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Barremian–Aptian Praehedbergellidae of the North Sea area: a reconnaissance

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CONTENTS

Synopsis. The taxa of the Praehedbergellidae which have been obtained from sediments of Barremian and Aptian age, in the off-shore North Sea area, include species of the genera *Praehedbergella* Gorbachik & Moullade, *Blefuscuiana* Banner & Desai and *Lilliputianella* Banner & Desai. The definitions of *Praehedbergella* and *Blefuscuiana* are modified to enhance their distinction.

Praehedbergella includes the taxa *P. grigelisi* (Banner & Desai) *perforare* n.subsp., *P. pseudosigali* n.sp., *P. ruka* n.sp. (including *P. ruka contritus* and *P. ruka papillata* n. subspp.), *P. sigali* (Moullade) *sensu lato*, *P. tuschepsensis* (Antonova) and *P.* cf *handousi* (Salaj). *P. sigali* has been recognised to comprise three subspecies: *P. sigali* s.s., *P. sigali compacta* n.subsp., and *P. sigali rasilis* n.subsp.

Blefuscuiana includes *B. aptiana* (Bartenstein) (including *B. aptiana depressa* n.subsp. and *B. aptiana implana* n.subsp.), *B. daminiae* n.sp., *B. excelsa* (Longoria) *cumulus* n.subsp., *B. gorbachikae* (Longoria), *B. laculata* n.sp. (including *B. laculata alobata* n.subsp.), *B. occulta* (Longoria) *sensu stricto*, *B. occulta* (Longoria) *perforocculta* n.subsp., *B. praesimilis* n.sp., *B. rudis* n.sp. and *B. whittakeri* n.sp. Metatypes of *B. infracretacea* (Glaessner) are redescribed and their first SEM images are given; *B. infracretacea s.s.* possesses strongly developed perforation cones, but *B. infracretacea aptica* (Agalarova) lacks them.

Lilliputianella includes *L. similis* (Longoria) and *L. eocretacea* (Neagu).

No species of planispiral praehedbergellids (e.g. of the genera *Blowiella* or *Leupoldina*) have been found yet in the North Sea wells studied, and no taxa which could be referred to the macroperforate and muricate Hedbergellidae have yet been found in beds as old as Barremian and Early Aptian.

The species of the Praehedbergellidae which have been identified have been used to define five informal Zones, which have been found to range in age from Early and Late Barremian to Early and Late Aptian. The Earliest Aptian may be recognised by the oldest stratigraphical occurrence of the genus *Lilliputianella*.

INTRODUCTION

Members of the Praehedbergellidae are microperforate globigerines with trochospiral tests (at least in their initial growth stage) and non-muricate and non-pustulate test walls. They range in age at least from Hauterivian to Danian and have been recorded from localities as far west as northern Mexico (Longoria, 1974), as far north as North Yorkshire, England (Banner and Desai, 1988), as far south as the Walvis Ridge, South Atlantic (Caron, 1985) and as far east as offshore Abu Dhabi (Banner and Strank, 1987). Species now assigned to genera of this family have been known since 1938 (*Globigerina* sp. D9, Hecht, 1938, now *Blefuscuiana aptiana* (Bartenstein)), and many (including *Gorbachikella kugleri* (*Bolli*); *Praehedbergella sigali* (Moullade); *B. occulta* (Longoria) and *Lilliputianella kuhryi* (Longoria)) have been used as zonal indices by previous workers (e.g. Bandy, 1967; Longoria, 1974; Sigal, 1977; Grigelis and Gorbachik, 1980; Gorbachik and Kuznetsova, 1983 and Banner and Desai, 1988).

The most comprehensive recent work on the Praehedbergellidae is that by Banner and Desai (1988) in their review and revision of the Jurassic–Early Cretaceous Globigerinina. These authors summarized the known stratigraphic ranges and phylogenetic affinities of all the contained genera of the Praehedbergellidae (three of the five of which were erected by them) as well as of some of the species. From this work it appears that some of the praehedbergellids may be usable for stratigraphic subdivision of part of the Early Cretaceous (Banner and Desai, 1988, fig. 1). The new data came, however, solely from Late Aptian assemblages of Speeton, north Yorkshire; none of the older Cretaceous beds at Speeton have been found to contain any planktonic foraminifera (it is probable that the Berriasian–Early Aptian deposits there were formed in water which was too shallow). Therefore, deeper-water deposits from the North Sea area were studied. Subseabed samples (cores and side-wall cores) from four wells, drilled (by BP Petroleum Development Ltd and Britoil plc) in the Cromer Knoll Group of the Central North Sea, were used. The correlation and dating of these sample-sequences had been determined by palynology and micropalaeontology, aided by lithostratigraphy and seismostratigraphy; the taxonomic determination of the praehedbergellid assemblages recorded here were, therefore, largely independent of any biostratigraphic conclusions which they may have suggested.

It is to be hoped that our results will help further our knowledge of the phylogeny of the Praehedbergellidae, and particularly aid in refining the planktonic foraminiferal biostratigraphy of deep-water sediments of Barremian to Aptian age.

PRACTICAL TAXONOMY AND BIOSTRATIGRAPHY

The generic characteristics recorded here (see below) can usually be readily distinguished by examination with an optical stereomicroscope, but we have found it to be essential to study these small praehedbergellids by SEM before final distinctions between members of the species-groups can be determined.

For the latter, we have used the methods of taxonomy

employed by Banner and Desai (1988) and which have also been used for other very small globigerines (belonging to *Praetenuitella* Li Qianyu, *Tenuitella* Fleisher, and *Tenuitellinata* Li Qianyu) by Li Qianyu (1987). In particular, we have preferred to 'split' rather than to 'lump', while recognising that future studies may show at least some of our species or subspecies to be synonyms. It will be easier, in the future, to synonymise rather than to separate; it would be especially difficult to disentangle the biostratigraphic records of forms which would now be referred to separate taxa.

Criteria within the species-groups

We have used the following characters to distinguish between species or subspecies of similar test size:

(a) the height of coiling, number and shape of the chambers in each of the whorls, as seen dorsally;

(b) the rate of increase in chamber size with growth (either rapid or gradual);

(c) the degree of intercameral sutural depression at the periphery (measured here by the angle between the chambers, the 'intercameral angle of sutural depression', at the periphery);

(d) the size and relative depth of the umbilicus (the latter being determined primarily by the degree of overhang of the chambers of the last whorl; it may be shallow or deep);

(e) the number of chambers seen ventrally to actually abut the umbilicus in the last mature whorl;

(f) the shape of the aperture (e.g. slit-like or high-arched);

(g) the nature of the test-wall surface (whether or not there are perforation-cones).

Although most of the morphocharacters used can, with experience, be recognised by optical stereomicroscopy in well-preserved specimens, the perforation-cones (similar to those figured for *Blefuscuiana* by Banner and Desai, 1988, pl. 3, fig. 5b) may still be difficult to see optically. To overcome this practical difficulty we have defined the species *sensu lato* to encompass forms with and without perforation-cones (but otherwise morphologically identical) and regard the presence or absence of perforation cones as of subspecific importance. Groups which differ only in a single character (e.g. chamber height *or* the magnitude of the intercameral angle of sutural depression) are usually also given only subspecific status.

Criteria within the genus-group

The distinction between *Praehedbergella* and *Blefuscuiana*, applied by Banner and Desai (1988) needs modification in the light of new data presented here. Banner and Desai (1988) distinguished *Praehedbergella* from *Blefuscuiana* by the presence of 4–4½ rather than 5 or more chambers per whorl. Specimens with 6½ chambers in the penultimate whorl reducing to 4½ in the last whorl, however, also exist (e.g. Pl. 2, fig. 1c). Moreover, there are species in which the last whorl is clearly seen to be made of 5 chambers when viewed from the dorsal side, but only part of the fifth is seen ventrally; this may be visible at the periphery only (e.g. Pl. 2, fig. 4a–c), or it may extend into the umbilicus (e.g. Pl. 3, figs. 1a–c, 6a–c).

Any distinction based on the number of chambers in the final whorl is, of course, arbitrary. Nevertheless, since forms with only 4 chambers surrounding the umbilicus in the last whorl have been recorded from strata of Hauterivian (see *P. handousi* Salaj, 1984, figs. 2a–c) to Late Aptian (e.g. *P. grigelisi* Banner and Desai, 1988, pl. 2, figs. 8–13) age, while those with more than 4 such chambers are known to range from the Early Barremian (e.g. *B. laculata* n.sp. *s.s.*, Pl. 2, figs. 1–5) to the Early Danian (e.g. *B. archeocompressa* (Blow, 1979)), it is necessary to distinguish between these morphologies so that they may be used to biostratigraphic advantage.

In consequence, we redefine the genus *Praehedbergella* as containing individuals in which the umbilical limits are formed by 4 chambers only; part of a fifth chamber may be visible ventrally at the periphery, but this chamber does not extend into the umbilicus (e.g. *Praehedbergella pseudosigali* n.sp., Pl. 2, figs. 1a–c). In such forms, the dorsal (spiral) side may disclose that the last whorl is made of 5 chambers, as in some species of *Blefuscuiana* (e.g. *B. laculata s.s.*, Pl. 3, figs. 1a–c), but in the latter genus the 5 chambers of the last whorl, which are visible ventrally, all abut the umbilicus.

To assign specimens either to *Praehedbergella* or to *Blefuscuiana* without recognising any intermediate forms is, perhaps, misleading in that it suggests that the distinction between the two is discrete. This, in fact, is not the case and there are assemblages where the two intergrade (e.g. see *P. sigali s.s.* and *B. laculata s.s.* below); in other words, the evolution from *Praehedbergella* to *Blefuscuiana* illustrates 'phyletic gradualism'.

Biostratigraphy with morphological criteria

No Barremian or Early Aptian samples have been found (or are known to have been recorded) to contain muricate and macroperforate Hedbergellidae. Only the microperforate, non-muricate Praehedbergellidae, often with perforation-cones, are known from sediments of these ages.

It appears that the stratigraphically earliest specimens that may be assigned to *Praehedbergella* (e.g. those of *P. handousi* figured by Salaj, 1984, from the Early Hauterivian of Tunisia) had 4 chambers in each of the penultimate and the final whorls. By the Early Barremian, some (e.g. those of *P. sigali s.l.*, Pl. 2, figs. 2–3) had 4–4½ chambers in each of these whorls, while others (e.g. *P. pseudosigali* n.sp., Pl. 2, figs. 1a–c) had developed 6 chambers in the penultimate whorl, with almost 5 in the final whorl when seen dorsally, but only 4 abut the umbilicus ventrally.

The earliest known members of *Blefuscuiana* (Early Barremian) include forms with between 4 and 5 chambers abutting the umbilicus ventrally (e.g. *B. laculata s.l.*, Pl. 3, figs. 1–5 and *B. daminiae s.l.*, Pl. 3, figs. 6 and Pl. 4, figs. 1–3) as well as those with 5–6 such chambers (e.g. *B. aptiana* (Bartenstein), Pl. 7, figs. 1–4, and *B. praesimilis* n.sp., Pl. 8, figs. 4–6). Morphologically more advanced forms with 7 or 8 chambers in the final whorl are not known below the Late Aptian (e.g. *B. occulta* (Longoria, 1974), and *B. multicamerata* Banner and Desai, 1988). Since forms with 5 chambers in their last whorls occur through to the last occurrence of the genus (Early Danian) the 5–6 last-chambered forms are not separated generically from those with 7 and 8 such chambers. It is, however, worth noting that the latter have not yet been recorded in beds younger than the Early Albian.

Lilliputianella, with its later chambers higher than broad when seen dorsally, was not found below the Aptian at Speeton (Banner and Desai, 1988), and the earliest stratigraphical appearance of this praehedbergellid morphology

appears to be in the earliest Aptian of the drilled sequences examined by us from the Central North Sea.

PREVIOUS WORK ON NORTH SEA BARREMIAN-APTIAN PRAEHEDBERGELLIDAE

Although outlines of the lithostratigraphy and micropalaeontology of Cretaceous of the North Sea Basins have been published (e.g. by King *et al.*, 1989), no detailed research on Barremian–Aptian planktonic foraminifera from the North Sea Basins has yet been publicly recorded. Several authors have described the broad succession of planktonic foraminiferal assemblages, but the work was done before the detailed revision of the genera and species from the Late Aptian of the area was published (Banner and Desai, 1988). Consequently, most of the taxa described in the present paper have been consistently referred to in print, collectively and incorrectly, as '*Hedbergella infracretacea*'. We include a revision of that taxon in this paper, and it can now be included among the many species referable to *Blefuscuiana*.

Ball (in Lott *et al.*, 1985) recorded and figured '*Hedbergella infracretacea*' from borehole 81/40 in the western margin of the Central North Sea Basin, and described a flood abundance of the species in a red mudstone clearly correlatable with the V5 Unit (*ewaldi* Marl) fauna described below in the present paper. The inadequacy of the figure and the lack of written description, however, prevents the allocation of Ball's specimens to particular taxa described in the present paper.

Crittenden (1987) discussed the Aptian planktonic foraminifera recovered from wells in Southern North Sea block 49. This essentially stratigraphical paper did not provide figures or descriptions of the globigerinid taxa. However, the paper did contain a general description of the succession of Aptian planktonic foraminiferal faunas which can be related to the Central North Sea sequence reported in this present paper. Crittenden (1987) reported the occurrence of '*Hedbergella aptiana*', with grey-coloured preservation, at the base of the Lower Holland Marl Member (although this taxon was shown by him to range higher, on his figure 4). This was recorded to be succeeded, in block 49, by a major flood of red-stained '*H. aptiana*' (referred to as red-stained '*H. infracretacea*' in the text of the paper) in the mid-part of the Lower Holland Marl. On gamma-ray and sonic logs, this unit seems similar to the V6 Unit of the Valhall Formation in the Central North Sea, and the contained microfauna very probably correlates directly with that given for Zone 4 in the present paper. At the top of the Lower Holland Marl Member, Crittenden (1987) recorded the presence of a green-stained assemblage referred to the '*H. infracretacea* group'; he believed this to be of Late Aptian age, on the basis of its content of the benthonic foraminifera *Saracenaria spinosa* Eichenberg and *Gaudryina dividens* Grabert, suggesting to Crittenden an equivalence with the *nolani-jacobi* Zones of the Northwest German Upper Aptian (Bartenstein and Kaever, 1978; King *et al.*, 1989). However, *G. dividens* has also been reported from beds of the Speeton Clay as old as Early Barremian (Lott *et al.*, 1985).

King *et al.* (1989) described from the Southern and Northern North Sea (i.e. south and north, respectively, of the Mid-North Sea High) a succession of planktonic foraminifera comparable to that given by Crittenden (1987). However, they described the three Aptian zones described by Crittenden (and as described here) to a single '*Hedbergella infracretacea*' Zone, called 'FCS7' in the Southern North Sea and 'FCN7' in the Northern North Sea. This 'zone' was referred to the Early Aptian–Late Aptian interval, and was said to comprise two planktonic foraminiferal events. The upper '*H. infracretacea*' occur in a calcereous claystone in which the calcareous microfossils exhibit a green, grey or grey-brown colour of preservation. Down section, red-stained '*H. infracretacea*' occur abundantly, originating from a red mudstone. These two 'events' clearly correspond to zones 4 and 5 of the present account.

Although King *et al.* (1989) also noted the presence of '*Hedbergella spp*' in the Mid Barremian *Gavelinella barremiana* Zone, none of the species or specimens were described in detail.

Crittenden *et al.* (1991) briefly recorded the occurrence of distinctive planktonic foraminiferal assemblages in the Lower Cretaceous of the Central North Sea. However, no taxonomic discussion or figures of the species were provided, as the paper was essentially lithostratigraphic — the only biostratigraphic information given was that needed to support the lithostratigraphy. The authors (Crittenden *et al.*, *op. cit.*) reported the development of three planktonic foraminiferal associations within the Aptian beds, comparable to those described by Crittenden (1987) from the Southern North Sea. An upper assemblage (comprising green-stained '*H. infracretacea*' and '*Globigerinelloides spp*') at the base of the Sola Formation was interpreted as being indicative of the Late Aptian *nutfieldensis* Zone transgression. This was followed down-section by a red-stained assemblage at the top of the Valhall Formation (V6 Unit), the characteristic species being referred to as '*Hedbergella* D11 Hecht, 1938'. This was interpreted as being earliest Late Aptian to latest Early Aptian in age. This contrasts with the age interpretation given by Crittenden (1987) as late Early Aptian for (probably) the same red-stained fauna occurring in the Southern North Sea block 49 wells. In the Central North Sea (Crittenden *et al.*, 1991), the lowest assemblage referred to the Aptian was that called '*Hedbergella* D9 Hecht, 1938' (= '*H. aptiana*' Bartenstein, also now referable to *Blefuscuiana* and discussed below in this paper); it occurred in the V5 Unit (Fischschiefer), and the specimens were often flattened, typically pyritised, with grey colour and black speckling. These 'events' clearly relate to zones 3, 4 and 5 of the present account (Fig. 4, p. 19).

From the Barremian, Crittenden *et al.* (1991) recorded the presence of '*Hedbergella spp*' in the Valhall Formation V4 Unit (said to be of 'Late to Middle Barremian' age). This assemblage probably corresponds to the Zone 2 association described in the present paper. No mention was made of planktonic foraminifera in the Lower Barremian of the Central North Sea, which is surprising as the Early Barremian fauna (Zone 1 herein) is widespread and distinctive — although it could be misinterpreted as a caved assemblage when found in cuttings samples.

Our biostratigraphic conclusions follow our account of the systematic descriptions and taxonomy of the species so far encountered, and are summarised in Fig. 4.

MATERIAL AND METHODS

This reconnaissance study is based on washed samples from the Cromer Knoll Group (basal Sola Formation and upper part of the Valhall Formation) drilled in three wells (15/30–3, 16/28–6RE and 20/2–2) of the Central North Sea area.

The subsurface samples were from cores, sidewall cores and cuttings, and the first two enabled errors of recorded distribution (caused by caving of specimens in the cuttings) to be avoided. The specimens were small but had to be picked and initially sorted optically; representatives of each sorted group were mounted on small pieces of photographic bromide paper for stereoscanning electron photomicrography; no liquid adhesives were used, so that the test-surfaces remained unaffected. Three views of each specimen (using contact prints from 35 mm negative film) were made to avoid errors of identification. It was found that the SEM imagery enabled recording of the significant morphology which could then be recognised using the optical microscope. The reverse procedure alone (i.e. using SEM imagery only as a final, illustrative, but not as an initial, research tool) was found to be prone to mistakes. Once the essential morphology of the taxa was understood, then their distribution in the wells was determined.

All holotypes, paratypes and hypotypes from the North Sea area, with the other specimens listed, are deposited in the Micropalaeontology collections, Department of Palaeontology, The Natural History Museum, London SW7 5BD, and all are registered with catalogue numbers prefixed 'P', as given in this paper. The specimens of *Blefuscuiana infracretacea s.s.* (= *Globigerina infracretacea* Glaessner) are two of the three specimens in the same slide (no. 689757) and are returned to the Department of Paleontology, National Museum of Natural History, Smithsonian Institution, Washington DC 20560, USA.

SYSTEMATIC PALAEONTOLOGY

All figured specimens, and many others which are referred to, are deposited in the Department of Palaeontology, The Natural History Museum, London. The depths given for the samples refer to those below the kelly bushing ('BKB') on the drilling rig, and, for accuracy and reliability of record, are given as they were initially and correctly recorded, i.e. in metres for the samples from Well 16/28–RE, and in feet for those from wells 20/2–2 and 15/30–3.

Superfamily GLOBIGERINACEA Carpenter, Parker and Jones, 1862

Family **PRAEHEDBERGELLIDAE** Banner and Desai, 1988

Genus **PRAEHEDBERGELLA** Gorbachik and Moullade, 1973

TYPE SPECIES. *Globigerina tuschepsensis* Antonova, 1964.

DIAGNOSIS EMENDED. Test a low trochospiral of 2 or more whorls, with 4–5 chambers visible in the dorsal aspect of the final whorl, but with only 4 chambers abutting the margins of the ventral umbilicus. The chambers are not radially elongate; the spiral side is evolute and the ventral side almost wholly involute. The aperture is intra-extraumbilical, interiomarginal, with a porticus; there are no accessory or supplementary apertures. The wall is calcitic, microperforate and lacks muricae or keels.

REMARKS. The need for this emendation is explained above (Practical Taxonomy and Stratigraphy; Criteria within the genus-group) in order more precisely to distinguish *Praehedbergella* from the longer-ranging genus *Blefuscuiana*.

Praehedbergella grigelisi Banner & Desai ***perforare*** n. ssp. Pl. 1, figs. 1a–d

NAME. After *perforare*, to pierce through, referring to the presence of perforation cones.

DIAGNOSIS. Characterized by the presence of perforation cones, the low trochospire, the relatively few chambers (about 5) in the first whorl, rapid opening of the spire and apparently narrow slit-like aperture.

PROVENANCE OF TYPES.
Holotype. P52758, from North Sea Well 20/2–2, 8300 m, Earliest Aptian; Pl. 1, figs. 1a–d.
Paratypes. From North Sea Well 16/28–6RE; P52759 (4275 m), P52762 (4204 m) (both Early Barremian), P52760 (4000 m), P52761 (4075 m) (both Late Aptian).

DESCRIPTION. Adult test about 0.20 mm at its maximum diameter and comprises at least two whorls of chambers coiled in a low trochospire. There are about 5 chambers in the penultimate whorl, reducing to 4 or 4½ chambers in the last whorl. The spiral side is almost flat or slightly convex and the intercameral sutures are moderately depressed; the intercameral angle of sutural depression at the periphery is about 135°. The chambers themselves are symmetrical and increase significantly in size with growth, those (excluding the final chamber) in the last whorl become slightly depressed, being about 2/3 as high as long when viewed from the spiral side. The final chamber may be only slightly longer than high. The umbilicus is shallow and measures about 0.35 mm in diameter. The aperture appears to be a narrow slit and perforation cones are visible at least on chambers of the last whorl.

REMARKS. The presence of perforation cones in this subspecies is of particular interest since these have not previously been recorded for any member of this genus. In the related genus *Blefuscuiana*, forms exist with identical gross morphologies which may be distinguished only by the presence or absence of perforation cones (e.g. *B. aptica* (Agalarova) *sensu stricto, B. infracretacea* (Glaessner) (metatypes redescribed in this paper) and its perforation-cone-bearing equivalents called 'cf. *aptica*' by Gorbachik, 1986, and by Banner & Desai, 1988). Since several such pairs are known for this genus (see below) we now regard the presence or absence of perforation cones as being only of subspecific value. Similarly, in *Praehedbergella*, we use perforation-cones to distinguish subspecies when the gross morphology of the taxa is otherwise identical.

Although *P. grigelisi perforare* resembles in all but generic characters the juvenile form of *B. aptica depressa*, the two do not occur consistently together and we regard them here as taxonomically separate.

P. grigelisi is *nomen correctum* for *P. grigelisae* Banner & Desai, 1988.

DISTRIBUTION. Central North Sea: Well 16/28–6RE

(4000 m, 4075 m, 4204 m and 4275 m); Well 20/2–2 (8300 m).

STRATIGRAPHY. Early Barremian to Late Aptian.

Praehedbergella pseudosigali n.sp. Pl. 2, figs. 1a–c

NAME. After superficial similarity of this species to *P. sigali*.

DIAGNOSIS. Characterized by the presence of perforation cones, low trochospire, relatively large number of chambers (about 6½) in the penultimate whorl, gradual opening of the spire and high-arched aperture.

PROVENANCE OF TYPE.
Holotype. P52735, Pl. 2, figs 1a–c. From Central North Sea Well 20/2–2, Late Barremian (8370 m).

DESCRIPTION. Test about 0.25 mm at its maximum diameter, consisting of two whorls of chambers coiled in a low trochospire. There are about 6½ chambers in the penultimate and 4½ in the last whorl. The spiral side is only slightly convex, with intercameral sutures forming intercameral angle of sutural depression at the periphery of about 145°. The chambers themselves are symmetrical and increase in size gradually with growth, those (excluding the final chamber) in the last whorl become depressed, being about half as high as long (compared with about 2/3 as high as long in the final chamber) on the spiral side. The umbilicus is small and the aperture is a high arch, with a very narrow porticus. Perforation cones are visible on chambers of the last whorl.

REMARKS. The presence of perforation cones, the numerous (about 6½) chambers in the first whorl, and the high-arched aperture is sufficient to describe this as a new species, and in particular to distinguish it from *P. sigali* (Moullade) *sensu lato*.

DISTRIBUTION. Central North Sea (Well 20/2–2, 8370 m).

STRATIGRAPHY. Late Barremian.

Praehedbergella ruka n.sp. *sensu lato*.
Pl. 1, figs. 2a–c, 3a–c, 4a–b, 5a–c.

NAME. After the Norwegian *ruka*, meaning a heap, stack or pile, referring to the 'heap' of chambers forming the high spire and very convex dorsal surface.

DIAGNOSIS. Characterized by its high trochospire, strong dorsal convexity (and 4 to 4½ chambers in the last whorl).

DESCRIPTION. Test about 0.15 mm at its maximum diameter, comprising about three whorls coiled in a high trochospire. There are 5 chambers in the penultimate whorl but 4–4½ in the final whorl. The spiral side is strongly convex and the intercameral sutures are moderately depressed forming intercameral angles of about 135°–140° at the periphery of the test. The chambers are symmetrical and increase in size gradually with growth. The chambers in the last whorl are either slightly depressed (about 2/3 as high as long when viewed from the spiral side), or depressed (about half as high as long when viewed dorsally). The final chamber may be about as high as long. The umbilicus is small and the aperture is a narrow slit.

REMARKS. This species of *Praehedbergella* has a dorsal convexity greater than that of any other known species of the genus, but which is matched only by a new species of *Blefuscuiana* (*B. cumulus*) described below.

STRATIGRAPHY. Aptian.

Praehedbergella ruka n.sp. *sensu stricto* Pl. 1, figs. 2a–c

DIAGNOSIS. Characterized by its high trochospire, strong dorsal convexity, slightly depressed chambers (about 2/3 as high as long) in the last whorl (excluding the final chamber which may be subglobular), and a smooth test surface lacking perforation cones.

PROVENANCE OF TYPES.
Holotype. P52739, Pl. 1, figs. 2a–c; from Central North Sea Well 16/28–6RE, Early Aptian (4157.5 m).
Paratypes. P52740, P52741, both from Well 16/28-6RE, Early Aptian (4150.5 m).

REMARKS. *P. ruka ruka* is distinguished from the other *ruka* subspecies by having only slightly depressed chambers and by lacking perforation cones.

DISTRIBUTION. Central North Sea.

STRATIGRAPHY. Early Aptian.

Praehedbergella ruka contritus n.sp., n.subsp.
Pl. 1, figs. 3a–c, 4a–b

1978 *Hedbergella infracretacea gargasiana* (Moullade), Caron: 652–656, 658; Pl. 1, figs. 7–9 (*not Globigerina infracretacea* Glaessner subsp. *gargasiana* Moullade, 1961).
1982 *?Hedbergella hoterivica* (Subbotina), Crittenden: 30–31, Pl. 2, figs. 1–2.

NAME. After *contritus*, a worn down object, referring to the depressed chambers in the last whorl.

DIAGNOSIS. Characterized by its high trochospire, strong dorsal convexity, depressed chambers (excluding the last) in the final whorl (about half as high as long when viewed spirally), and a smooth test surface lacking perforation cones. The final chamber may be subglobular.

PROVENANCE OR TYPES.
Holotype. P52737, Pl. 1, figs. 3a–c; from Central North Sea Well 16/28–6RE, Late Aptian (3989.5 m).
Paratype. P52738, Pl. 1, figs. 4a–b; from Central North Sea Well 20/2–2, Early Aptian (8250 ft).

REMARKS. The specimens of *P. ruka* figured by Caron (1978) came from beds she believed to be upper Aptian and which were in the lowest core obtained from DSDP Site 364, Angola Basin; unfortunately, she misidentified it as '*Hedbergella infracretacea gargasiana* Moullade', a form which has 5½ high, undepressed chambers in the final whorl, and which is referable either to *Blefuscuiana* or to *Hedbergella* (with a muricate test surface). The only resemblance between *P. ruka* and Moullade's form is the great convexity of the dorsal side. The holotype of *P. ruka contritus* occurred in the Upper Aptian but it may be reworked there; we have not seen evidence for its occurrence in beds of Late Aptian age elsewhere. We suspect that the earliest cores retrieved from DSDP Site 364 were, in fact, of Early Aptian age.

A similar form has been figured by Crittenden (1982) from the Atherfield Clay (Early Aptian) of the Isle of Wight,

southern England. He called it '*Hedbergella hoterivica*', but that species belongs to the genus *Favusella* (Banner & Desai, 1988); Crittenden's specimens posses a high spire and dorsal convexity, and lack perforation-cones, but their re-examination is necessary before identity with this subspecies is confirmed.

DISTRIBUTION. Angola Basin and Walvis Ridge, southeastern Atlantic Ocean; Central North Sea; ?southern England.

STRATIGRAPHY. Early–?Late Aptian.

Praehedbergella ruka papillata n.sp., n.ssp.
Pl. 1, figs. 5a–c

NAME. After *papillatus*, with buds (referring to the presence of abundant perforation cones).

DIAGNOSIS. Characterized by its high trochospire, strong dorsal convexity, depressed chambers (excluding the last) in the final whorl, a papillate test surface, covered with abundant perforation cones, and a thick porticus. The final chamber may be subglobular.

PROVENANCE OF TYPES
Holotype. P52736; Pl. 1, figs. 5a–c, from Central North Sea (Well 16/28–6RE), 4150 m, Early Aptian.

REMARKS. This subspecies appears not to have been recognised by any previous workers. Although it is distinguished by the presence of its perforation cones, it can be morphologically otherwise identical to the typical form of the species (see Pl. 1, compare figs. 5c and 3c). *P. ruka papillata* appears to be analogous to *Guembelitria cretacea* Cushman, which also has perforation cones formed over its microperforations, while *P. ruka ruka* would be analogous to *Gallitellia vivans* (Cushman), which has a smooth microperforate surface (see Loeblich and Tappan, 1988, Pl. 485, figs. 1–3, 11–12); such distinctions were used by Loeblich and Tappan (1988, p. 453) to distinguish between the genera *Guembelitria* and *Gallitellia*. However, we use this criterion to distinguish only subspecies (not even species, much less genera) because we, as yet, do not know of any stratigraphic difference between the geological ranges of these taxa (in contrast, *Guembelitria* ranges Cretaceous–Palaeogene, while *Gallitellia* is Quaternary). However, the geographical distribution of the subspecies may prove to be different.

The thick, broad, heavy porticus, which appears to characterise *P. ruka papillata* (Pl. 1, fig. 5a) is apparently not typical for other taxa which bear perforation cones, either in the Globigerinacea (e.g. *P. grigelisi perforare*, Pl. 1, fig. 1a, and *Blefuscuiana infracretacea* (Glaessner), Pl. 4, fig. 2, Pl. 8, fig. 1) or the Heterohelicacea (e.g. *Cassigerinella boudecensis* Pokorny, see Li Qianyu, 1986).

DISTRIBUTION. Central North Sea.

STRATIGRAPHY. Early Aptian.

Praehedbergella sigali (Moullade) *sensu lato*.
Pl. 2, figs. 2a–c, 2a–c

1966 *Hedbergella* (*Hedbergella*) *sigali* Moullade; 87–88: Pl. 7, figs. 20–25.

DIAGNOSIS EMENDED. A species of *Praehedbergella* in which the number of chambers in each of the penultimate and last whorls is 4 to 4½, the chambers are anteriorly-posteriorly symmetrical (the highest part of each chamber being in the middle of its length), and the aperture is narrow. The intercameral sutures form intercameral depressions at the periphery of about 125° to about 140°. Perforation cones have never been recorded in this species.

REMARKS. The aperture is a narrow slit, not a broad arch as it is in *P. pseudosigali*. The spiral side is not strongly convex as it is in *P. ruka*. The chambers of the last whorl are symmetrical, their greatest height being at the mid point of their length; this differs from the asymmetrical chambers figured by Gorbachik (1986) for topotypic *P. tuschepsensis*.

The chambers of the last whorl vary in height from being subglobular to weakly depressed; the holotype microphotographed by Moullade (1966, Pl. 7, figs. 24–25) has subglobular chambers, of height almost as great as their length (when viewed from the spiral side), and correspondingly deep intercameral sutures at the test periphery (which make angles of about 125–130° between the chambers). This form is regarded here as *H. sigali sensu stricto* (i.e. *H. sigali sigali*, see below). In contrast, other forms of this species have depressed chambers, which have heights about half their lengths (when viewed from the spiral side), in their final whorls; these latter are separated by us as two new subspecies (*compacta* n.subsp. and *rasilis* n.subsp., see below) distinguished by the magnitude of their peripheral intercameral angles and overall appearance of their tests.

STRATIGRAPHY. Early Barremian–Late Aptian (see subspecies below).

Praehedbergella sigali (Moullade) *sensu stricto*
Pl. 2, figs. 2a–c

1966 *Hedbergella (Hedbergella) sigali* Moullade: 87–88, *pars*; Pl. 7, figs. 21, 24–25 (*non* 20, 22, 23).
1985 *Hedbergella sigali* Moullade, Caron: 59; fig. 25 (22a–b, *non* 21a–c).
Non *Hedbergella sigali* Moullade, Kuhry, 1974, p. 231, Pl. 2, figs. 6a–c, 8.
Non *Hedbergella sigali* Moullade, Longoria, 1974, p. 68, Pl. 21, figs. 6–8, Pl. 22, 1–13.

REMARKS. Moullade (1966) erected *Hedbergella sigali* and distinguished it from *H. delrioensis* by its smaller, less coarsely perforate test with a less rugose surface. These criteria, together with the Early Barremian–Early aptian range of the species, later led Banner and Desai (1988) to suggest that '*Hedbergella*' *sigali* should be referred to *Praehedbergella*. Although it is acknowledged that further work on the primary types or topotypes is needed before this can be made certain, the view taken by Banner and Desai (op. cit.) is adopted here.

Kuhry (1974) assigned specimens from S.E. Spain with 4–5 chambers in the last whorl to '*Hedbergella*' *sigali*, but only figured individuals with 5 and 6 such chambers. Consequently Kuhry's specimens are better assigned to *Blefuscuiana* and are not included here in the synonymy of *P. sigali*. Similarly, specimens figured by Longoria (1974), in which the chambers are distinctly longer than high, are not regarded as conspecific with *P. sigali*. Some of these (1974, Pl. 22, figs. 1–5) have been referred to *P. tatianae* Banner and Desai (1988), others (1974, Pl. 22, figs. 9–13) are referable to *Blefuscuiana*; the remaining specimen is deformed and indeterminate.

PROVENANCE OF HYPOTYPES. P52742 (Pl. 2, fig. 2), P52743,

both North Sea Well 20/2–2, 8680 ft, Early Barremian; P52744 (4150.5 m, Early Aptian), P52745 (4010 m. Late Aptian), both North Sea Well 16/28–6RE.

DISTRIBUTION. Central North Sea; Hautes-Alpes, southeastern France.

STRATIGRAPHY. Moullade (1966) reported *H. sigali* (including forms assigned here to *H. sigali rasilis* n.ssp.) as ranging from the Early Barremian–Early Aptian and this range is also recorded here for typical forms of this species. However, a single occurrence was also observed in the Late Aptian of Well 16/28–6RE (at 4010 m); this may be a true range extension but it may be a record of a reworked specimen (the sample originates from within a basin fan facies).

Praehedbergella sigali (Moullade) ***compacta*** n. ssp.
Pl. 2, figs. 3a–c

1966 *Hedbergella* (*Hedbergella*) *sigali* Moullade: 87–88 *pars*; Pl. 7, fig. 20.

NAME. After the more 'compact' outline of the test compared with *P. sigali sigali*.

DIAGNOSIS. A subspecies of *P. sigali* (Moullade) *sensu lato*, characterized by chambers which (sometimes excluding the final chamber) become depressed in the last whorl and have heights about half their lengths (when viewed from the spiral side), by relatively shallow intercameral sutures, which form intercameral angles of about 150° at the test periphery, and by a 'compact' test outline.

PROVENANCE OF TYPES.
Holotype. P52746 (Pl. 2, figs. 3a–c), from Central North Sea Well 20/2–2, 8680 ft (Early Barremian).
Paratypes. All from Central North Sea Well 16/28-6RE; P52753 (4189 m), P52752 (4204 m), P52756 (4225 m), all Early Barremian; P52748–P52751, P52754, P52755, P52757, all 4150.5 m, all Early Aptian.

DESCRIPTION. Test about 0.10–0.15 mm at its maximum diameter, comprising about two whorls, each with 4½ chambers coiled in a low trochospire. The spiral side is almost flat or slightly convex. The depressions of intercameral sutures at the periphery of the test form angles of about 150° between adjacent chambers. The chambers themselves are symmetrical and increase in size gradually with growth and become depressed, being almost half as high as long when viewed on the spiral side (excluding the final chamber); the final chamber is only slightly lower than long. The umbilicus measures about 0.02 mm in diameter, and the aperture is a narrow slit with a narrow porticus. Perforation cones are not present.

REMARKS. The 'compact' test outline in this species is apparently a consequence of the depressed chambers combined with the relatively shallow intercameral sutural depressions at its periphery.

A specimen figured by Moullade (1966, Pl. 7, fig. 20) resembles this species but has been photographed at a slightly oblique angle and should, therefore, only tentatively be included here in synonymy.

DISTRIBUTION. Central North Sea (Well 16/28–6RE, 4150.5 m, 4160.7 m, 4200 m; Well 20/2–2, 8680 m); ?Hautes-Alpes, southeastern France.

STRATIGRAPHY. Early Barremian–Early Aptian.

Praehedbergella sigali (Moullade) ***rasilis*** n. ssp.

1966 *Hedbergella* (*Hedbergella*) *sigali* Moullade: 87–88 *pars*; Pl. 7, figs. 22–23.
1985 ?*Hedbergella sigali* Moullade, Caron: 59 *pars*; figs. 25 (21a–c).
1986 *Clavihedbergella sigali* (Moullade), Gorbachik: 236; Pl. 24, figs. 1–2.

NAME. From Latin, *rasilis*, 'scraped, shaved, smoothed, polished', referring to the more rounded appearance of the test compared with *P. sigali sigali*.

DIAGNOSIS. A subspecies of *P. sigali sensu lato* characterized by its depressed chambers in the last whorl, which are about half as high as long, moderately depressed intercameral sutures, which form intercameral angles of about 140° at the periphery of the test, and a moderately lobate test outline (compared to the strongly lobate test of *P. sigali sigali*).

PROVENANCE OF TYPE.
Holotype. specimen figured by Gorbachik, 1986, Pl. 24, fig. 1, from Katsa, Verkhoretse, southwestern Crimea, U.S.S.R.; Late Barremian.

DESCRIPTION. Test about 0.20 mm at its maximum diameter, composed of about 2 whorls, coiled in a low trochospire, each with about 4½ chambers. Spiral side almost flat or slightly convex. Intercameral sutures forming angles of about 140° between chambers at the periphery of the test. The chambers are symmetrical and increase in size gradually with growth and become depressed, being almost half as high as long when viewed from the spiral side, in the last whorl. The aperture is a narrow slit bordered by a narrow porticus. The test surface lacks perforation cones.

REMARKS. The only published specimens definitely assigned to this species are those recorded by Moullade (1966) and Gorbachik (1986). The specimen figured by Caron (1985) is morphologically very similar, but it has not been described, the nature of its wall is obscure, and its stratigraphic primary provenance is uncertain (it was not mentioned by Caron, 1978, but she thought it to have come "from lower Aptian levels reworked in Albian sample" when she later figured it in 1985).

This subspecies has not so far been recorded from the North Sea.

DISTRIBUTION. Southern U.S.S.R.; Hautes-Alpes, southeastern France; ?Walvis Ridge, South Atlantic Ocean.

STRATIGRAPHY. Recorded as ranging from Early Barremian–Early Aptian, i.e. the same range as recorded by Moullade (1966) for *Praehedbergella sigali s.s.*.

Praehedbergella tuschepsensis (Antonova)
Pl. 2, figs. 4a–c

1964 *Globigerina tuschepsensis* Antonova: 59–60; pl.'12, fig.'3a–c.
1986 *Clavihedbergella tuschepsensis* (Antonova), Gorbachik: 118–9, 236; Pl. 25, fig. 1.

REMARKS. When Antonova (1964) erected *Globigerina tuschepsensis*, she published only drawings of her new species. Later, Gorbachik (1986) used scanning electron micrographs to illustrate a topotypic specimen (1986) with clearly asymmetric chambers (with greatest height about two-thirds

of their length towards the posterior). This character is exhibited by the North Sea specimens and is unknown in any other species of this genus.

PROVENANCE OF HYPOTYPES. P52733 (Pl. 2, fig. 4), from central North Sea Well 16/28–6RE, 4150.5 m, Early Aptian.

DISTRIBUTION. Central North Sea (Well 16/28–6RE, 4150.5 m to 4250 m); Southern U.S.S.R.

STRATIGRAPHY. Recorded from the Barremian to Early Aptian of the southern U.S.S.R. (Antonova, 1964 and Gorbachik, 1986) and from the Early Barremian to Early Aptian of the Central North Sea.

Praehedbergella sp. cf. ***P. handousi*** (Salaj, 1984)
Pl. 2, figs. 5a–c

REMARKS. The specimens assigned here resemble '*Caucasella*' *handousi*, a species erected by Salaj (1984, from the Early Hauterivian of Tunisia) but are smaller (0.12 mm in maximum diameter, compared with 0.3 mm for the type specimens of the species). Moreover, the initial chambers in the North Sea specimens are not clearly seen.

PROVENANCE OF HYPOTYPE. P52734, from Central North Sea Well 20/2–2, 8680 ft, Barremian.

Genus **BLEFUSCUIANA** Banner & Desai, 1988

TYPE SPECIES. *Blefuscuiana kuznetsovae* Banner & Desai, 1988.

DIAGNOSIS EMENDED. A Praehedbergellid as originally diagnosed, and which has 5 or more chambers abutting the umbilicus. The trochospiral test may have perforation-cones or a porticus or both, but it is always irregularly microperforate, not regularly macroperforate, and it lacks muricae.

REMARKS. The diagnosis has had to be emended in order more clearly and precisely to distinguish this taxon from *Praehedbergella* Gorbachik and Moullade. The adult chambers of both *Praehedbergella* and *Blefuscuiana* are no higher than long when seen dorsally, and have rounded, low peripheries; in contrast, *Lilliputianella* Banner and Desai has chambers which are higher than long when seen dorsally, and which develop narrowly elongate, sometimes even radially pointed, peripheries.

Blefuscuiana aptiana (Bartenstein, 1965) *sensu lato*
Pl. 6, figs. 4a–b, 5, 6a–b, 7; Pl. 7, figs. 1a–c, 2a–c, 3a–c, 4a–c.

REMARKS. When erecting this species, Bartenstein (1965) cited Hecht's (1938) figured specimens as the type series. Later, Banner and Desai (1988) pointed out that the holotype of *B. aptiana* (Hecht's Pl. 23, fig. 60; Bartenstein's text-fig. 3) appears to be deformed or abnormal and they used the paratypes for identification of the species. Although Bartenstein (1965) figured only drawings, it is apparent that these type specimens each comprise about 2 whorls coiled in a low trochospire, and have flat spiral sides; they have 5–6 chambers in their last whorls and intercameral sutural angles of about 120°–130° at the periphery of their tests. Their chambers are only slightly depressed (i.e. 2/3 or more as high as long when viewed spirally) and their test surfaces appear to be completely smooth, without perforation cones. These specimens are taken here to be typical of *B. aptiana* (i.e. of *B. aptiana s.s.*). Other morphologies which differ only in having more depressed chambers and/or possess perforation cones, however, are also included by us in the species *sensu lato* but are separated at subspecific level (see *B. aptiana depressa, B. aptiana implana* below).

STRATIGRAPHY. Barremian–Late Aptian (see subspecies below). The species has previously been recorded from the Southern North Sea (Crittenden, 1987, from block 49) and the Central North Sea (Crittenden *et al.*, 1991); these records were from beds of the basal Aptian (basal Lower Holland Marl Member and in the V5 Unit respectively). The basal Aptian acme of this species is widespread in the North Sea area, and this is seen here in the sample from 8300 ft depth, well 20/2–2, where it has a characteristic grey colouration with black speckles, originating from the pyritic and organic-rich sediments of the V5 Unit (Fischschiefer Member). This correlates with the characteristics of the same unit in north-west Germany, at which level the species was recorded by Hecht (1938) (see *B. aptiana sensu stricto*). Specimens from this horizon are commonly pyritised to varying degrees, due to the anoxicity of the bottom waters of this time (conditions represented by the Fischschiefer Member).

Blefuscuiana aptiana (Bartenstein) *sensu stricto*
Pl. 6, figs. 4a–b, 5, 6a–b

1938 ?*Globigerina* sp. D9 Hecht: 17; Pl. 23, fig. 60.
1938 *Globigerina* sp. D9 Hecht: 17; Pl. 23, figs. 61–63.
1965 *Hedbergella aptiana* Bartenstein: 347–348, text-figs. 3?, 4–6.
1979 *Hedbergella aptiana* Bartenstein; Sigal: 318; Pl. 2, figs. 24, 25.
1988 *Blefuscuiana aptiana* (Bartenstein); Banner & Desai: 158, figs. 1–3.
1988 *Blefuscuiana occulta* (Longoria) *quinquecamerata* Banner & Desai: 162–163; Pl. 7, figs. 9–11.

REMARKS. This species is characterised by having a relatively flat spiral side, an open umbilicus, which the chambers of the last whorl do not overhang significantly, 5–6 chambers in the last whorl, only slightly depressed chambers (about 2/3 as high as long when viewed dorsally) in the last whorl, and by the absence of perforation cones.

PROVENANCE OF HYPOTYPES. P52665 (Pl. 6, fig. 6), P52667 (Pl. 6, fig. 5), P52672, all from the Early Aptian, North Sea Well 16/28–6RE, 4178.5 m. P52675, from the Early Barremian, North Sea Well 20/2–2, 8600 ft. P52669, Well 16/28–6RE, 4100 m, Late Aptian. P52670, Well 16/28–6RE, 4150.5 m, Early Aptian. P52671, Well 16/28–6RE, 4160.7 m, Early Aptian. P52666 (Pl. 6, fig. 4), North Sea Well 20/2–2, 8300 ft, Early Aptian. P52668, Well 16/28–6RE, 4075 m, Late Aptian. P52673, Well 20/2–2, 8210 ft, Late Aptian. P52674, Well 20/2–2, 8300 ft, Early Aptian. P52676, Well 15/30–3, 12830–12840 m, Early Aptian.

DISTRIBUTION. Central North Sea (Wells); North-West Germany; Vigo Seamount, 200 kms offshore from Portugal (west of Oporto).

STRATIGRAPHY. Previously recorded from the Early to Late Aptian of Europe, the typical form of this species is now

recorded from the Early Barremian to the Late Aptian of the North Sea.

Blefuscuiana aptiana (Bartenstein) ***depressa*** n.subsp.
Pl. 6, fig. 7; pl. 7, figs. 1a–c

NAME. After the depressed form of the chambers in the last whorl.

DIAGNOSIS. A subspecies of *B. aptiana* characterised by having depressed chambers (about half as high as long when viewed from the spiral side), and by lacking perforation cones.

PROVENANCE OF TYPES.
Holotype. P52711, Pl. 7, figs. 1a–c; from North Sea Well 16/28–6RE, 4260 m, Early Barremian.
Paratype. P52712, Pl. 6, fig. 7; from North Sea Well 20/2–2, 8300 ft, Early Aptian.

DESCRIPTION. Test about 0.15–0.2 mm at its maximum diameter, comprising about 2–3 whorls coiled in a low trochospire, each with 5–5½ chambers. The spiral side is almost flat or slightly convex and the intercameral sutures are moderately depressed, forming angles of about 130°–135° at the periphery of the test. The chambers are symmetrical and increase in size gradually with growth, becoming depressed in the second and (when present) third whorl, being about half as high as long when viewed dorsally. The last chamber may be about as high as long. The umbilicus is 'open' and the aperture appears to be a narrow slit. The test surface lacks perforation cones.

REMARKS. The depressed chambers in the last whorl of this species, combined with the absence of perforation cones distinguishes this subspecies from others of *B. aptiana*.

DISTRIBUTION. Central North Sea (Wells).

STRATIGRAPHY. Early Barremian–earliest Aptian.

Blefuscuiana aptiana (Bartenstein) ***implana*** n.subsp.
Pl. 7, figs. 2a–c, 3a–c, 4a–c

NAME. After *implanus*, uneven, referring to the rough surface of the test resulting from the presence of perforation cones.

DIAGNOSIS. A subspecies of *B. aptiana* characterised by having perforation cones.

PROVENANCE OF TYPES.
Holotype. P52705, Pl. 7, figs. 2a–c; from North Sea Well 20/2–2, 8210 ft, Early Aptian.
Paratypes. P52706, Pl. 7, figs. 4a–c; from Well 20/2–2, 8210 ft, Late Aptian. P52707, Pl. 7, figs. 2a–c; from Well 20/2–2, 8370 ft, Late Barremian.

DESCRIPTION. Test about 0.15–0.2 mm at its maximum diameter, comprising about 2–3 whorls coiled in a low trochospire. There are 5–6 chambers in each of the penultimate and last whorls. The spiral side is almost flat or slightly convex and the intercameral sutures are moderately depressed, forming angles of about 130°–140° at the periphery of the test. The chambers are symmetrical and increase in size gradually with growth, they are typically subglobular to slightly depressed (about 2/3 as high as long when viewed from the spiral side) in the last whorl, although in some the first 1–2 chambers in the last whorl may be more strongly depressed (about half as high as long). The umbilicus is broadly open and the aperture is a narrow slit. Perforation cones are present on chambers of the last whorl.

REMARKS. This subspecies differs from others of *aptiana* in having perforation cones.

DISTRIBUTION. Central North Sea (Well).

STRATIGRAPHY. Late Barremian–Late Aptian.

Blefuscuiana daminiae n.sp.
Pl. 3, figs. 6a–c; Pl. 4, figs. 1a–b, 3a–c

NAME. After Damini Desai, who took some initial SEM photographs and helped begin this phase of the study.

DIAGNOSIS. Characterised by having 5 chambers in the last whorl of which only part of the first is seen ventrally, thereby giving an overall subquadrangular appearance to the test and by a deep umbilicus, resulting from the distinct overhang of the chambers in the last whorl.

PROVENANCE OF TYPES.
Holotype. P52696 (Pl. 3, figs. 6a–c), from North Sea Well 15/30–3, 12830–12840 ft, Early Aptian.
Paratypes. P52699 (Pl. 4, fig. 3), from same sample as holotype. P52697, from North Sea Well 16/28–6RE, 4150.5 m, Early Aptian. P52698 and P52700, both from North Sea Well 20/2–2, Early Aptian, from 8300 ft (Pl. 4, figs. 1a–c) and 8250 ft respectively.

DESCRIPTION. Adult test about 0.20 mm at its maximum diameter, comprising at least 2 whorls coiled in a low trochospire. There are 5 chambers in each of the penultimate and last whorls. The spiral side is slightly concave to slightly convex and the intercameral sutures are moderately depressed, forming intercameral angles of about 140°–150° at the periphery of the test. The chambers are symmetrical and increase gradually in size with growth. They are subglobular in the penultimate whorl and depressed to slightly depressed (about 1/2–2/3 as high as long, when viewed from the spiral side) in the last turn of the spire, with the first two chambers in the latter tending to be more depressed than the last three. The final chamber may be almost as high as long. The umbilicus is small and deep; the aperture appears to be a narrow slit.

REMARKS. This species most closely resembles *B. infracretacea aptica* but differs in having only part of the first chamber in the last whorl visible ventrally. *B. daminiae* therefore appears to be morphologically less evolved than *B. infracretacea aptica*. Since *B. daminiae* is known only from the Early Aptian, while *B. infracretacea aptica* has been found in beds of Early to Late Aptian age (see below) it seems possible that *B. daminiae* may be the ancestral form.

The much more rapid chamber enlargement in the last whorl of this species, as seen dorsally, easily distinguishes it from *B. laculata s.l.*.

Although the holotype lacks perforation-cones and possesses a smooth surface, perforation-cones may be present on some specimens (e.g. Pl. 4, fig. 3a); these may merit subspecific distinction, but further study has yet to be made.

DISTRIBUTION. Central North Sea (wells).

STRATIGRAPHY. Early Aptian.

Blefuscuiana excelsa (Longoria) *sensu lato*

1974 *Hedbergella excelsa* Longoria: 55, 56; pl. 18, figs. 6–11, 14–16.

REMARKS. This is the only publicly described species of *Blefuscuiana* which has a high spire and a very convex dorsal surface. Specimens exactly matching the described type specimens, which must represent the typical form of the species *sensu stricto*, are not as yet known from the North Sea area; those which have been found are referred to the new subspecies, described below.

Blefuscuiana excelsa (Longoria) ***cumulus*** n.subsp. Pl. 6, figs. 1a–c, 2a–c

NAME. From *cumulus* meaning a heap or pile, referring to the chambers forming the high spire.

DIAGNOSIS. Characterised by its high spired test, with its very convex dorsal surface, and by having 5 chambers in the last whorl.

PROVENANCE OF TYPES.
Holotype. P52708, Pl. 6, fig. 1a–c; from North Sea Well 15/30–3, 12830–12840 m, Early Aptian.
Paratypes. P52709 (Pl. 6, figs. 2a–c), P52710, both from North Sea Well 16/28–6RE, 4150.5 m, Early Aptian.

DESCRIPTION. Test about 0.20 mm at its maximum diameter, comprising about 2–3 whorls coiled in high trochospire. There are about 5 chambers in each of the penultimate and last whorls. The spiral side is strongly convex, and the intercameral sutures are moderately depressed, forming angles of about 135°–140° at the periphery of the test. The chambers are symetrical and increase in size gradually with growth, becoming depressed, being about half as high as long in the last whorl (when viewed from the spiral side). The umbilicus is small and deep, and the aperture is probably a narrow slit. Perforation-cones have not been found on this species.

REMARKS. *B. excelsa cumulus* differs from *B. excelsa* (Longoria) *sensu stricto* by its fewer chambers per whorl — the latter has at least six. *B. excelsa s.s.* has been recorded only from the Early Aptian; *B. excelsa cumulus* is also known in this study, only from the Early Aptian of the North Sea area.

DISTRIBUTION. Central North Sea (Wells).

STRATIGRAPHY. Early Aptian.

Blefuscuiana gorbachikae (Longoria). Pl. 6, figs. 3a–c

1974 *Hedbergella gorbachikae* Longoria: 56–58; pl. 15, figs. 1–16.
1985 *Hedbergella gorbachikae* Longoria; Caron: 1985: 31, 59; figs. 25.8–9.
1988 *Blefuscuiana gorbachikae* (Longoria); Banner & Desai: 160, 162; pl. 5, figs. 8–12 (including synonymy).

REMARKS. This species is characterised by its flat dorsal side, convex ventral side and strongly umbilically directed last chambers.

PROVENANCE OF TYPES. Early Aptian, P52687 (Pl. 6, fig. 3), P52689, both from North Sea Well 16/28–6RE, 4150.5 m. Early Aptian, P52688, from North Sea Well 20/2–2, 8300 ft, and P52690, from North Sea Well 15/30–3, 12830–12840 ft.

DISTRIBUTION. Mexico; subseabed Walvis Ridge and Angola Basin, southeastern Atlantic (DSDP Leg 40, sites 363 and 364 respectively); Central North Sea (Wells); Speeton, North Yorkshire, England; southeastern France; Spain; Southern U.S.S.R.

STRATIGRAPHY. Previously recorded as ranging from the Late Aptian to Early Albian (Caron, 1985; Banner and Desai, 1988), this species is reported here from the Early Aptian of the Central North Sea. The range given by Longoria (1974) must be extended.

Blefuscuiana infracretacea (Glaessner) *sensu lato*

REMARKS. As Longoria (1974, p. 59) wrote, this species-group name "has served as a 'waste-basket' name. . .; almost every Lower Cretaceous species with unknown affinity has been referred to this species". Re-examination of type specimens (which are illustrated here) at last enables it firmly to be placed in its correct genus and its species-characters to be recognised. This species is characterised by having 5–6 chambers in the last whorl, with a small, deep umbilicus; the flattened dorsal surface of this species has symmetrical, predominantly depressed chambers (about half as high as long when viewed dorsally) in the last whorl; the intercameral sutures are nearly radial.

B. infracretacea is distinguished from *B. daminiae s.l.* in having at least 5 chambers almost wholly visible on the ventral side with a correspondingly more pentagonal (rather than roughly quadrangular) test outline; it differs from *B. excelsa cumulus* by its lower spire (spiral side almost flat to moderately convex, compared to strongly convex; compare Pl. 4, figs. 4b, 5b, 6b, Pl. 5, figs. 1b, 2b, 3b & 5b, with Pl. 6, figs. 1b & 2b), and from *B. gorbachikae* (Longoria) by lacking the very strongly umbilically-directed last chambers diagnostic for that species (see Pl. 6, figs. 3a).

STRATIGRAPHY. Early to Late Aptian–?Albian, see subspecies below.

Blefuscuiana infracretacea (Glaessner) *sensu stricto* Pl. 4, fig. 2a–c; Pl. 8, fig. 1a–c

1936 *Globigerina infracretacea* (Glaessner; 28, text-fig. 1.
1966 *Hedbergella infracretacea* (Glaessner), Glaessner: 179–184; Pl. 1, figs. 1a–3c.
1986 *Hedbergella aptica* (Agalarova), Gorbachik: 94; pl. 14, figs. 4, 5 (*not* 2, 3).
1988 *Blefuscuiana* cf. *aptica* (Agalarova), Banner & Desai: 160; pl. 3, figs. 4, 5a, 5b.

REMARKS. Glaessner (1966) reported that this species was originally collected in 1935 from dark calcareous clay, then dated as Albian, exposed in the valley of the River Ubin, at Ilskaya, Northwest Caucasus, U.S.S.R. He (1966, p. 180) carefully and thoroughly redescribed the gross morphology of the species, basing his work on 24 topotype specimens from the original collection. Three of these specimens were given to the U.S. National Museum, Washington, D.C., were claimed (1966, p. 184) to have been registered in the U.S.N.M. Catalogue No. 130 as specimens 642370–72, and were drawn for publication by L.B. Isham (Glaessner, 1966, pl. 1).

Isham's drawings showed the presence, on the test surface, of knobbly projections which could be either muricae or perforation-cones. The drawings showed perforations in a

stylised way, and it was not clear whether the test was microperforate or macroperforate. Glaessner's redescription (1966) was equally vague on these points. Therefore, it was not possible to be sure if the species was a small, early *Hedbergella* or a late *Blefuscuiana*. Consequently, three topotype specimens, which had been collected by Glaessner in 1935, were borrowed from the U.S.N.M.; although they are catalogued as number 689757 (not as recorded by Glaessner, 1966), there can be no doubt, from their provenance and shape, that these are the specimens which were drawn by Isham, and they probably are metatypes.

Scanning Electron Photomicrography of these specimens (Pl. 4, fig. 2; Pl. 8, fig. 1) shows that Banner & Desai (1988, p. 160) and Hart *et al.* (1989, pp. 346–347) were wrong, that the species is not muricate or macroperforate, and is not to be referred to *Hedbergella*. Instead, it has irregularly spaced microperforations, which are covered by the most prominent perforation-cones yet seen in the Praehedbergellidae. Nothing like them exists in the post-Albian Globigerinacea, and only the Heterohelicacea had genera (*Cassigerinella, Guembelitria*) which possessed them in Late Cretaceous and younger times. The specimen called '*Hedbergella* cf. *aptica* (Agalarova)' by Gorbachik (1986, pl. 15, figs. 1, 2), from the 'Middle' Aptian of Alma, Crimea, U.S.S.R., has similar perforation-cones and may be the same as *B. infracretacea* from the Caucasus, but Gorbachik's illustrations do not show enough of the gross morphology to enable the reader to be certain.

Specimens identical to the Glaessner topotypes (Banner & Desai, 1988, pl. 3, figs. 4, 5a–b) confirm that the early whorls, on the dorsal surface of the test, are covered by thick lamellae of calcite which seal most of the early perforations, and that (ventrally) the primary aperture lacks a porticus. It is as though the species secreted the calcite not needed for its chambers on the chamber surfaces rather than around the aperture. The early dorsal perforation-cones are thus smothered in secondary lamellae, and those of the last chambers are weak because they have not yet been built up by the development of such lamellae—the cones are most prominent on the earlier chambers of the last whorl. These observations are confirmed by Glaessner's description (1966, p. 180): "The sculpture of the walls . . . first increases and then . . . decreases during growth of additional chambers. . . No projecting apertural lips have been observed." These support the emendation of the diagnosis of *Blefuscuiana*: these microperforate, non-muricate tests may have perforation-cones or a porticus or both.

STRATIGRAPHY. *B. infracretacea* (Glaessner) has been found in the latest Aptian, *Acanthoplites nolani* zone, at Sarstedt, Saxony, Germany (Banner & Desai, 1988, p. 156, pl. 3, figs. 4, 5). The known range of the species, *sensu stricto*, is therefore Late Aptian ('Middle' Aptian in Gorbachik's (1986) sense is early Late Aptian); also, it may occur in the Albian if Glaessner's (1936) dating of the R. Ubin exposure was correct, but this has not yet been confirmed.

Blefuscuiana infracretacea (Glaessner) *aptica* (Agalarova)

Pl. 4, figs. 4a–c, 5a–c, 6a–c

1951 *Globigerina aptica* Agalarova: 49; pl. 8, figs. 9–11.
1960 *Globigerina infracretacea* Glaessner subsp. *trochoidea* Moullade: 136; pl. 2, figs. 21, 23–25.
1961 *Globigerina infracretacea* Glaessner subsp. *gargasiana* Moullade: 214 (new name).
1986 *Hedbergella aptica* (Agalarova); Gorbachik: 94; pl. 14, figs. 2, 3 (*not* 4–5).
1988 *Blefuscuiana aptica* (Agalarova); Banner & Desai: 160; pl. 5, figs. 4–7.

REMARKS. This subspecies is morphologically almost identical to *B. infracretacea* (Glaessner) *sensu stricto* but possesses a porticus and lacks perforation-cones. The surfaces of the chamber walls are smooth. Agalarova (1951) noted that the proloculus stands out clearly on the dorsal side, showing that there is no heavy coating of secondary lamellae obscuring the early whorls; also, her original drawings show the presence of a porticus but give no indication of the presence of any other projections on the test surface.

Another morphological difference which is useful stratigraphically is that the typical *Blefuscuiana infracretacea aptica* is more tightly coiled, with a narrower umbilicus, than the phylogenetically more advanced *B. infracretacea sensu stricto*.

PROVENANCE OF TYPES. P52701 (Pl. 4, figs. 4a–c), P52682 (Pl. 4, figs. 6a–c) and P52703, from North Sea Well 15/30–3, 12830–40 ft, Earliest Aptian; P52702 (Pl. 4, figs. 5a–c) and P52686 from North Sea Well 20/2–2, 8300 ft, Early Aptian; P52704, from North Sea Well 16/28–6RE, 4150.5 m, Early Aptian.

DISTRIBUTION. Central North Sea (Wells), southern U.S.S.R. (Azerbaidzhan), S.E. France, Atlantic (sea-bed).

STRATIGRAPHY. Early to Late Aptian. Agalarova's type specimens were obtained from the Aptian Khanaga Formation (eastern Azerbaidzhan), and Gorbachik (1986) figured specimens from the 'Middle' Aptian (early Late Aptian) of the Atlantic. Moullade (1960, 1961) obtained his specimens from the Late Aptian of south-east France. Banner & Desai (1988) illustrated it from the early Late Aptian of Speeton, Yorkshire, U.K. It has now been obtained from the Early Aptian of North Sea wells. *B. infracretacea aptica* appears to have older stratigraphic occurrences than *B. infracretacea s.s.*, and was probably its immediate ancestor.

Blefuscuiana laculata n.sp. *sensu lato*

Pl. 3, figs. 1a–c, 2a–c, 3a–c, 4, 5a–c

NAME. After *laculatus, -a, -um*, four-cornered, referring to the test outline.

DIAGNOSIS. Characterised by having 5 chambers in the last whorl, but with a test that is roughly quadrangular in outline, and by a broad, open umbilicus which the chambers do not overhang significantly.

DESCRIPTION. Test about 0.15–0.20 mm at its maximum diameter, comprising at least two whorls of chambers coiled in a low trochospire. There are 4–5 chambers in the penultimate whorl and 5 chambers in the final whorl. The spiral side is almost flat to slightly concave. The chambers are symmetrical and increase in size gradually with growth. The chambers are subglobular in the penultimate whorl, and subglobular to slightly depressed (about 2/3 as high as long when viewed from the spiral side) in the final whorl. The umbilicus is broad, but the aperture is a narrow slit. No perforation cones are known.

REMARKS. *B. laculata* clearly possesses 5 chambers abutting

the umbilicus in the last whorl (e.g. Pl. 3, figs. 1a–c), although only part of the first chamber of the last whorl may be seen ventrally. At first sight it resembles a species of *Praehedbergella*, and this, combined with its early stratigraphical range (i.e. Early Barremian) suggests that this species of *Blefuscuiana* had evolved directly from *Praehedbergella*.

The rate of enlargement of the chambers of the last whorl, as seen dorsally, is much slower than in *B. daminiae*; also the equatorial outline of *B. laculata* is more quadrangular than that of *B. daminiae*, which is more circular.

DISTRIBUTION. Central North Sea (wells); western Atlantic subseabed.

STRATIGRAPHY. Early Barremian.

Blefuscuiana laculata n.sp. *sensu stricto*

Pl. 3, figs. 1a–c, 2a–c

1979 *Clavihedbergella eocretacea* Neagu; Sigal: 290; pl. 3, figs. 31, ?30

DIAGNOSIS. Characterised by having a roughly quadrangular test outline, an open umbilicus, and intercameral sutures at the periphery of the test which form angles of about 120°–135°; the test surface lacks perforation cones.

PROVENANCE OF TYPES.
Holotype. P52724, Pl. 3, figs. 2a–c: from Central North Sea Well 20/2–2, 8680 ft, Early Barremian.
Paratype. P52725, Pl. 3, figs. 1a–c; from same sample as holotype.

REMARKS. *B. laculata s.s.* closely resembles *P. sigali s.s.* (see above) with which it occurs, the only significant difference being the number of chambers in the final whorl abutting the umbilicus (5 and 4 respectively; compare Pl. 3, figs. 1–2 with Pl. 2, fig. 2). The oldest known occurrence of both taxa is Early Barremian. Therefore, it seems likely that *P. sigali s.s.* gave rise to *B. laculata s.s.* shortly after the former taxon's first appearance; *P. sigali s.s.* itself ranges up to the Late Aptian.

DISTRIBUTION. Central North Sea (wells); subseabed Atlantic, offshore Portugal (DSDP Site 398).

STRATIGRAPHY. Sigal (1979) believed that this form was confined to the Barremian stage (as characterised by ammonites) in DSDP Site 398 (200 km off the coast of Portugal). We record it from the Early Barremian of the Central North Sea.

Blefuscuiana laculata alobata n.subsp.

Pl. 3, figs. 3a–c, 4, 5a–c

NAME. Referring to the less lobate test outline compared with the *B. laculata s.s.* (*loba* = lobe).

DIAGNOSIS. A subspecies of *B. laculata* characterised by having intercameral sutural angles at the periphery of about 130°–145°; the test surface lacks perforation cones.

PROVENANCE OF TYPES.
Holotype. P52726 (Pl. 3, figs. 3a–c), from central North Sea Well 20/2–2, 8680 m (Early Barremian).
Paratypes. P52727 (Pl. 3, figs. 5a–c), P52728 (Pl. 3, fig. 4), P52729, all from the same sample as the holotype.

REMARKS. This subspecies is distinguished from *B. laculata s.s.* in having less deeply depressed intercameral sutures at the periphery of the test. Although there is some overlap in the magnitude of this intercameral, peripheral angle between these taxa, the range that can be measured within a specimen is sufficient to distinguish clearly between the two subspecies.

The evolutionary relationship between *P. sigali s.s.* and *B. laculata s.s.* has been suggested above. Since the difference between *B. laculata s.s.* and *B. laculata alobata* (i.e., the magnitude of the intercameral sutural angle at the periphery of the test) is analogous to those between the subspecies of *P. sigali*, we regard it probable that the whole *P. sigali* species-group as having evolved, as a plexus, into that of *B. laculata*. However, we believe that it is worth distinguishing morphologically between the subspecies of each species because such distinctions clarify the taxonomy of the Praehedbergellidae as a whole and provide the potential for palaeo-environmental, or palaeobiogeographic, or biostratigraphic discrimination.

DISTRIBUTION. Central North Sea.

STRATIGRAPHY. Early Barremian.

Blefuscuiana occulta (Longoria) *sensu lato*

REMARKS. When Longoria erected *B. occulta*, he included only forms which lack perforation cones. Since we have found specimens in which perforation cones are present, but which are otherwise indistinguishable from *B. occulta sensu stricto*, we regard the species *sensu lato* to comprise both morphotypes.

STRATIGRAPHY. Late Barremian–Late Aptian (see subspecies below).

Blefuscuiana occulta (Longoria) *sensu stricto*

1974 *Hedbergella occulta* Longoria: 63–64; pl. 11, figs. 7–8; pl. 19, figs. 17–18; pl. 20, figs. 5–9, 17–18.
1976 *Hedbergella* aff. *planispira auct.* Sigal: pl. 2, figs. 1–2.
1988 *Blefuscuiana occulta* (Longoria); Banner and Desai: 162, pl. 6, figs. 8–12.

REMARKS. *B. occulta sensu stricto* is taken by us to be *B. occulta* as originally defined and illustrated (i.e. without perforation cones). A single specimen from the North Sea has 5½, rather than the usual 6–7 chambers in the last whorl.

DISTRIBUTION. Northern Mexico; Speeton, North Yorkshire, England; Central North Sea (Well 20/2–2, 8300 m, 8250 m); North Atlantic (DSDP Leg 47B, Site 398D, 200 m off the coast of Portugal, west of Oporto).

STRATIGRAPHY. Previously recorded from the Late Aptian of northern Mexico and Speeton, and from the Early Aptian of the North Atlantic, we have found this subspecies also to occur rarely in the Early Aptian drilled in the Central North Sea.

Blefuscuiana occulta (Longoria) ***perforocculta*** n.subsp.

Pl. 8, figs. 2a–c, 3

NAME. *Perfor-*, + *occulta*, the clearly perforate form of the species.

DIAGNOSIS. A subspecies of *B. occulta* characterised by having perforation cones marking the sites of the microperforations.

PROVENANCE OF TYPES.
Holotype. P52677 (Pl. 8, figs. 2a–c), from Central North Sea Well 20/2–2, 8300 m, Early Aptian.
Paratypes. P52678 (pl. 8, fig. 3), P52681, from the same sample as the holotype; P52679, from Central North Sea Well 15/30–3, 12830–12840 ft, Early Aptian, and P52680, from Central North Sea Well 16/28–6RE, 4014.37 m, Late Aptian.

DESCRIPTION. Test about 0.20–0.25 mm at its maximum diameter, comprising about 3 whorls coiled in a low trochospire. There are 5½–7 chambers in each of the penultimate and last whorls. The spiral side is almost flat. The intercameral sutures are depressed to form angles of about 130°–140° at the periphery of the test. The chambers are symmetrical, increase in size gradually with growth, and are typically subglobular. The umbilicus is broad and the aperture appears to be a narrow slit. Perforation cones are present dorsally and ventrally on the chambers of the last whorl.

REMARKS. This form is rare in the Late Barremian (so far found in beds of this age only in Well 20/2–2 at 8370 ft), but it occurs quite commonly in beds considered to be Early Aptian and it ranges up into Late Aptian sediments. Therefore, it appears older than *B. occulta sensu stricto*, and to acme earlier and to disappear earlier; it may prove to be the phylogenetically older form of the species.

DISTRIBUTION. Central North Sea (wells).

STRATIGRAPHY. Late Barremian–Late Aptian.

Blefuscuiana praesimilis n.sp. Pl. 8, figs. 4a–c, 5, 6

NAME. After similarity to *Lilliputianella similis*, which it precedes stratigraphically.

DIAGNOSIS. Characterised by a very broad umbilicus, subglobular chambers which become nearly as high as long when viewed dorsally, an almost planar dorsal side with depressed sutures, and a markedly lobulate equatorial periphery.

PROVENANCE OF TYPES.
Holotype. P52691 (Pl. 8, figs. 4a–b) from Central North Sea Well 20/2–2, 8680 ft, Early Barremian.
Paratypes. P52692 (Pl. 8, fig. 5), P52694, both from same sample as holotype; P52693 (Pl. 8, fig. 6), P52695, from the same well, at 8600 ft, also Early Barremian.

DESCRIPTION. Test about 0.15–0.20 mm at its maximum diameter, comprising about 2 whorls coiled in a low trochospire. There are about 5–6 chambers in the last whorl, but this is an ontogenetic increase as the penultimate may have only 4–5. The spiral side is almost flat, slightly concave or slightly convex, with depressed sutures, and the intercameral sutures form angles of about 140° at the periphery of the test, which becomes markedly lobulate. The chambers are symmetrical and increase in size gradually with growth. They are typically globular to slightly depressed (about 2/3 as high as long when viewed from the spiral side) in the last whorl. The umbilicus is very broad (about one-third of the test diameter). The aperture appears to be a narrow slit. Perforation cones have not been found on this species.

REMARKS. This species resembles *Lilliputianella similis* (compare Pl. 8, figs. 4–6 with Pl. 8, fig. 8), and is probably immediately ancestral to it, even though it is not yet known from the late Barremian. *B. praesimilis* is distinguished from *B. aptiana s.l.* in having a broader umbilicus.

DISTRIBUTION. Central North Sea (wells).

STRATIGRAPHY. Early Barremian.

Blefuscuiana rudis n.sp. Pl. 5, figs. 1a–c, 2a–c, 5a–c

NAME. After *rudis*, rough, unpolished, referring to the test surface which possesses perforation cones.

DIAGNOSIS. A bulky test with marked dorsal convexity and weakly depressed sutures, early chambers which are subglobular, but with predominantly depressed chambers in the last whorl (about half as high as long when viewed dorsally), and with perforation cones.

PROVENANCE OF TYPES.
Holotype. P52713 (Pl. 5, figs. 1a–c), from Central North Sea Well 16/28–6RE, 4275 m (Early Barremian).
Paratypes. P52714 (Pl. 5, figs. 5a–c), from same sample as holotype; P52715 (Pl. 5, figs. 2a–c), Central North Sea Well 20/2–2, 8250 ft (Early Aptian); P52716, Central North Sea Well 15/30–3, 12830–12840 ft (Early Aptian).

DESCRIPTION. Test about 0.15–0.30 mm at its maximum diameter, comprising about 3 whorls. There are 5–6 (commonly 6) chambers in each of the penultimate and last whorls. The spiral side is strongly convex. The intercameral sutures are weakly depressed and form intercameral angles of 150° or more at the periphery of the test. The chambers are symmetrical and increase in size gradually with growth; they are predominantly depressed in the final whorl, commonly being about half as high as long (when viewed on the dorsal side), but the penultimate chamber may be only slightly depressed (about 2/3 as high as long when viewed dorsally), while the last chamber may be subglobular. The umbilicus is small and deep and the aperture appears to be a narrow slit. Perforation cones are present on all chambers of the last whorl.

REMARKS. This species is distinctive because of its compact, almost plano-convex test, with low, depressed, symmetrical chambers, weakly depressed intercameral sutures, and a spire which appears to open only slowly when seen in dorsal view. The typical form has well developed perforation cones, but another subspecies, with a smooth surface, has not yet been found.

DISTRIBUTION. Central North Sea (wells).

STRATIGRAPHY. Early Barremian–Early Aptian.

Blefuscuiana whittakeri n.sp. Pl. 5, figs. 3a–c, 4

NAME. For J.E. Whittaker, The Natural History Museum, London, for his help in preparing the environmental chamber SEM photomicrographs of *B. infracretacea* (Glaessner) and for his enthusiastic support in this project.

DIAGNOSIS. Characterised by high, rapidly enlarging chambers, about 5 in each of the later whorls, forming a robust test with virtually radial and straight intercameral sutures, a flattened dorsal side and a very small ventral umbilicus.

PROVENANCE OF TYPES.
Holotype. P52717 (Pl. 5, figs. 3a–c, 4), from North Sea Well 15/30–3, 12830–12840 ft, Early Aptian.
Paratypes. P52718, from same sample as holotype; P52719 and P52720, from North Sea Well 20/2–2, 8250 ft and 8300 ft

respectively, both Early Aptian; P52721, P52722 and P52723, all from North Sea Well 16/28–6RE, 4250 m, 4225 m and 4275 m respectively, all Early Barremian.

DESCRIPTION. Test about 0.10 mm to 0.25 mm in maximum diameter; about three whorls of inflated, subglobular chambers, forming a test which is slightly convex or flattened dorsally, and convex ventrally with a small but deep umbilicus. The chambers enlarge rapidly, so that the last whorl increases the diameter of the test by more than 50% (i.e. from about 60% of the final diameter to 100%); the chambers are symmetrical (highest in their mid-parts) and are high when seen dorsally, becoming as high as long. The dorsal and ventral intercameral sutures are virtually straight and radial, and the terminal face is high, radial and flattened. The intercameral sutures are moderately depressed and make depressions of about 150° at the equatorial periphery. The aperture is a low slit. The surface of the typical form of the species is covered by low perforation cones (Pl. 5, fig. 4).

REMARKS. This species most clearly differs from *B. rudis* by its undepressed chambers which more rapidly enlarge and consequently increase the diameter of the test more rapidly (compare Pl. 5, fig. 3b with Pl. 5, figs. 1c, 2c and 5c), and by its narrower umbilicus; also, its dorsal intercameral sutures are straighter, more radial, and the dorsal surface of the test is flatter than in *B. rudis*. A form of this species which lacks perforation cones has not yet been recognised.

DISTRIBUTION. Central North Sea (Wells).

STRATIGRAPHY. Early Barremian–Late Aptian.

Genus **LILLIPUTIANELLA** Banner and Desai, 1988

TYPE SPECIES: *Lilliputianella longorii* Banner and Desai, 1988.

Lilliputianella eocretacea (Neagu)
Pl. 6, fig. 8, pl. 8, figs. 7a–c

1975 *Clavihedbergella eocretacea* Neagu: 112–113; pl. 89, figs. 1–10, text–fig. 20.

PROVENANCE OF TYPES. P52731 (Pl. 8, figs. 7a–c), North Sea Well 15/30–3, 12830–12840 ft, Early Aptian; P52732 (Pl. 6, fig. 8), North Sea Well 16/28–6RE, 4160.7 m, Early Aptian.

REMARKS. This species has less strongly depressed intercameral sutures, a smaller umbilicus, and the early chambers in the last whorl are depressed, not high or radially elongate.

This species was originally found (Neagu, 1975) in Romanian strata believed to be Late Barremian in age; this would be the stratigraphically oldest occurrence of *Lilliputianella*, but it needs confirmation. In the North Sea area and elsewhere (e.g. Longoria, 1974; Banner and Desai, 1988) this genus is not yet known from below the Aptian.

Neagu (1975) believed this species to have been evolved directly from *Praehedbergella sigali*; his species was recorded rarely to have four chambers in the last whorl, which would support this idea, but normally to have five (as in the holotype figured by Neagu, 1975, and in one hypotype, P52731) and rarely six (as in our P52732). It probably evolved in Late Barremian time from phylogenetically early *Blefuscuiana* (Banner & Desai, 1988).

DISTRIBUTION. Romania; Central North Sea (wells).

STRATIGRAPHY. Late Barremian?–Early Aptian.

Lilliputianella similis (Longoria) Pl. 8, figs. 8a–c

1974 *Hedbergella similis* Longoria: 68–69; pl. 16, figs. 10–21; pl. 18, figs. 12–13; pl. 23, figs. 14–16.
1981 *Hedbergella similis* Longoria; Tronchetti: 141–242; pl. 37, fig. 1–7.
1988 *Lilliputianella similis* (Longoria); Banner and Desai: 169; pl. 8, figs. 8–9.

PROVENANCE OF TYPES. P52730 (Pl. 8, figs. 8a–c), from North Sea Well 20/2–2, 8300 ft (Earliest Aptian).

REMARKS. The North Sea subseabed specimens do not differ in any significant respect from those recorded by Longoria (1974) or from those previously recovered from outcrop at Speeton (Banner & Desai, 1988).

DISTRIBUTION. Northern Mexico; France; Speeton, North Yorkshire, England; Central North Sea (Well 20/2–2, 8300 ft).

STRATIGRAPHY. Previously recorded from the Early to basal Late Aptian of Mexico, from the Late Aptian of France and the basal Late Aptian of Speeton (Yorkshire), it also occurs in the subseabed Earliest Aptian of the North Sea area.

THE BIOSTRATIGRAPHIC SIGNIFICANCE OF NORTH SEA BARREMIAN-APTIAN PRAEHEDBERGELLIDAE

This reconnaissance has recognised the occurrence of species of *Praehedbergella* and *Blefuscuiana* in sediments from Early Barremian to Late Aptian age, and, from Early Aptian strata, *Lilliputianella*. The planispiral, schackoinid genera *Blowiella* Kretchmar and Gorbachik and *Leupoldina* Bolli, although known from the Late Aptian outcrop of Speeton and from Barremian and Early Aptian beds of more southerly occurrence (Banner and Desai, 1988), have not yet been found by us in well samples from the Central North Sea. The recognised distributions of the species which have been found, in the samples from the wells studied, are shown on Figs. 1–3, and the biostratigraphic results are synthesised and summarised on Fig. 4.

One of us (PC) has worked on North Sea Lower Cretaceous planktonic foraminifera for a number of years. This has allowed the development and utilisation of a succession of five planktonic foraminiferal assemblages, within the Barremian–Aptian interval, for subsurface stratigraphical subdivision and correlation. This has resulted in the recognition of the stratigraphic divisions of the subsurface North Sea Early Cretaceous sequences and the dating of these divisions from combined foraminiferal, nannofossil and dinocyst evidence. Several of these assemblages have already been reported by previous workers on the micropalaeontology of the North Sea area (see the *Previous Work* discussed above), though the species were loosely referred to as '*Hedbergella infracretacea*', '*Hedbergella D9* of Hecht' and so on. As their taxonomy has now been revised, the assemblages can be more precisely described, and the stratigraphically significant assemblages

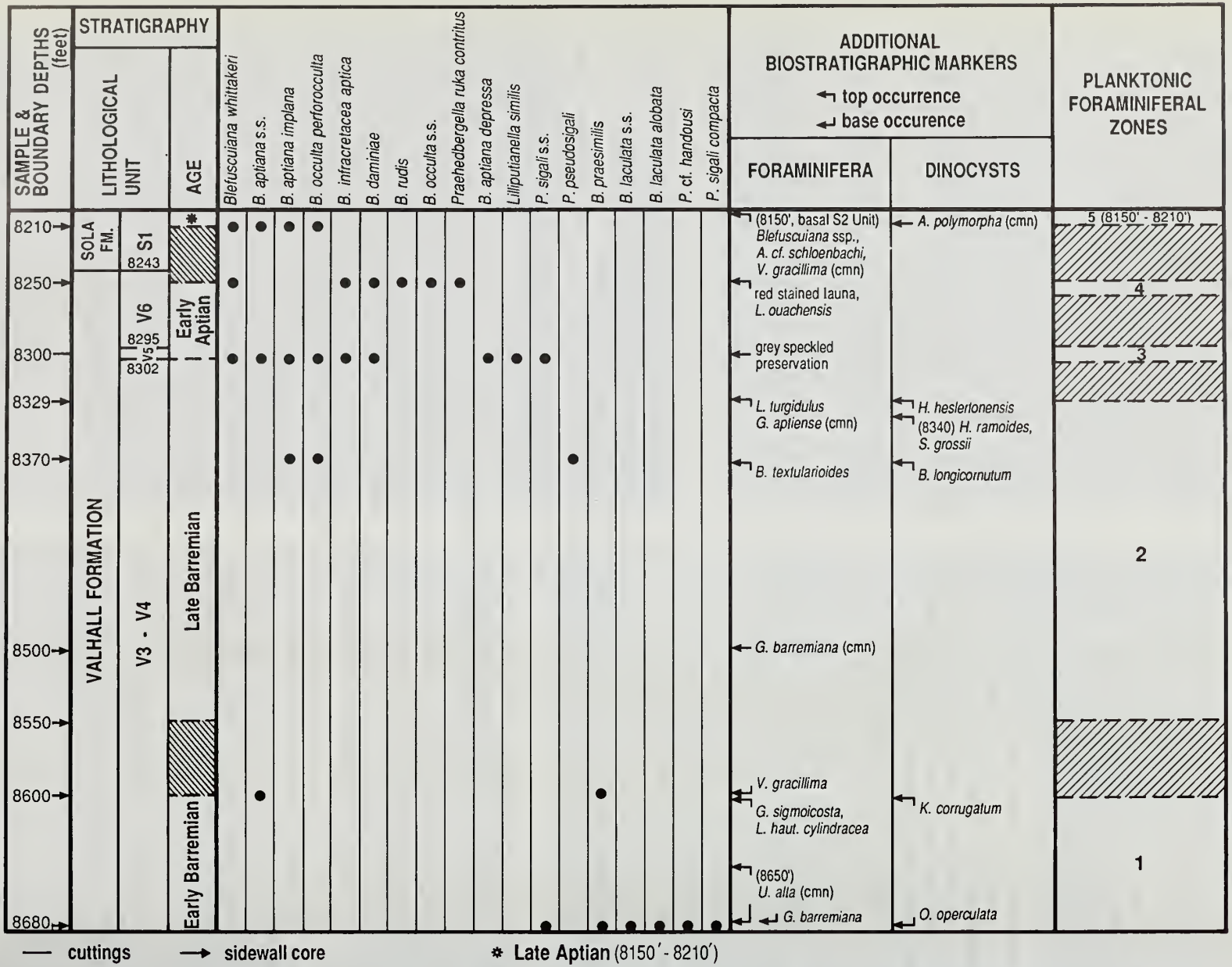

Fig. 1 Occurrences of taxa of the Praehedbergellidae in Central North Sea Well 20/2-2, Lower Barremian to Upper Aptian. Depths in stratigraphy columns refer to wireline log depths. Cross hatching refers to unstudied intervals between samples, with dashed horizontal lines indicating limits of proven age units. Boundaries marked by continuous lines have been taken at log features.

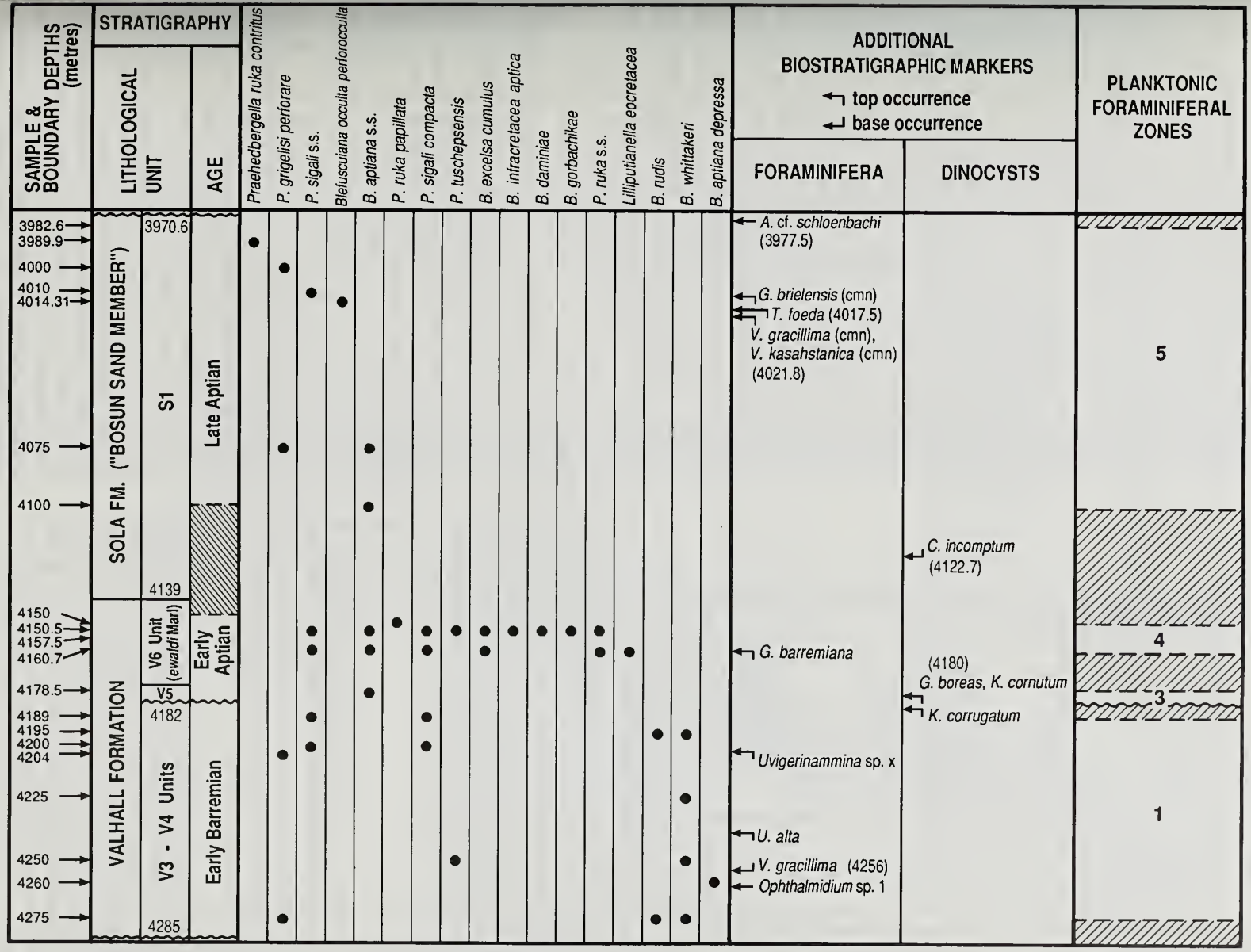

Fig. 2 Occurrences of taxa of the Praehedbergellidae in Central North Well 16/28-6RE, Lower Barremian to Upper Aptian. Depths in stratigraphy columns refer to wireline log depths.

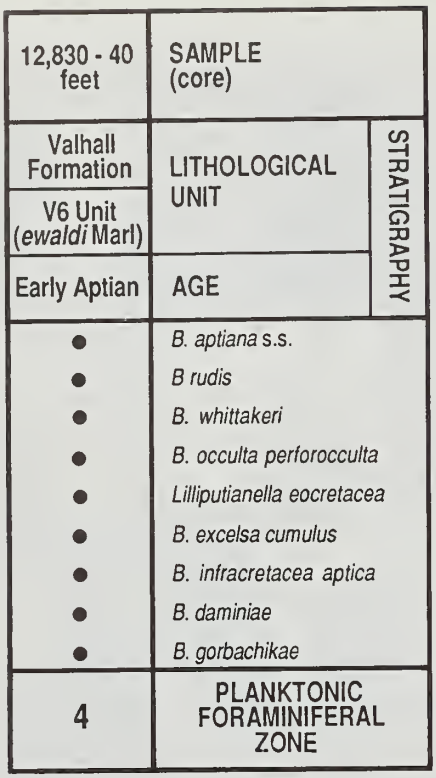

Fig. 3 Occurrences of red-stained taxa of the Praehedbergellidae in the Lower Aptian, *ewaldi* marl, lithological unit V6, Valhall formation, in Well 15/30–3, Central North Sea.

can be used to define a succession of five informal biozones as outlined below.

In the biozonal descriptions below, 'appearances' refer to stratigraphic bases (last downhole *in situ*, uncaved occurrences) while 'disappearances' refer to stratigraphic tops (first downhole occurrences). The associated occurrences of stratigraphically useful benthonic foraminifera, dinocysts and nannofossils are identified by the use of 'F', 'D' and 'N' respectively.

Zone 1

TAXA RESTRICTED TO ZONE 1. *Blefuscuiana praesimilis, B. laculata s.s., B. laculata alobata, Praehedbergella* cf *handousi*.

TAXA APPEARING IN ZONE 1. As above, plus *Praehedbergella grigelisi perforare, P. sigali s.s., P. sigali compacta, P. tuschepsensis, Blefuscuiana aptiana depressa, B. rudis, B. whittakeri*.

REMARKS. This zone contains the oldest common occurrence of Lower Cretaceous planktonic foraminifera in the North Sea basin, although rare, isolated specimens may occur below Zone 1, in the Hauterivian. This acme consists of members of the Praehedbergellidae, as the Favusellacea are as yet unknown from strata of Barremian age in the North Sea. The praehedbergellid influx is seen over a wide area, in well sections from west of Shetland to the central North Sea, and it forms a very useful biostratigraphic unit for correlation.

AGE AND STRATIGRAPHY. An Early Barremian age is indicated by the co-occurring benthonic foraminifera and dinocysts and by the correlated nannofossils. The top of Zone 1 coincides with the disappearances of *Kleithriasphaeridium corrugatum* (D) and *Gavelinella sigmoicosta* (F), and its base coincides with the appearances of *Gavelinella barremiana* (F), *Valvulineria gracillima* (F) and *Odontochitina operculata* (D). These overlapping occurrences indicate an Early Barremian age. Typically also occurring within Zone 1 is an abundance of *Uvigerinammina* spp referable to '*U.* sp. X' King *et al.* (1989) and *U. alta* (identified variously as *U. moesiana* or '*U. moesiana* subsp. A' in industry reports).

Zone 1 occurs within the Valhall Formation V3 Unit typically shortly beneath the Munk Marl Bed high-gamma claystone. In condensed sequences, on structural highs, the praehedbergellid association (together with the benthonic foraminifera mentioned above) occurs within a limestone facies referred to the Tuxen Formation (Jensen *et al.*, 1986; Crittenden *et al.*, 1991). In this facies, other benthonic foraminifera such as *Trocholina infragranulata, Aulotortus neocomianus, Patellina subcretacea* and *Spirillina* spp are common. Co-occurring nannofossil assemblages are stratigraphically useful. The zone contains the tops of *Conusphaera oblongata* and *C. salebrosus* (N), in downhole succession (Jakubowski, 1987). The latter event was dated as Early Barremian by Jakubowski (1987) and by Taylor (1982). The first downhole occurrences of *Stradnerlithus comptus* (N), common *Diazmolithus lehmanni* (N) and *Lithastrinus septentrionalis* (N) occur beneath the base of Zone 1, marking sediments of earliest Barremian age immediately below the base of that zone. *S. comptus* has been recorded from the *variabilis* ammonite zone (basal Barremian) at Speeton (Jakubowski, 1987). The latter nannofossil association occurs with the top of *Meandrospira washitensis* (F), an event used to mark the basal Barremian in the North Sea.

Zone 2

TAXA RESTRICTED TO ZONE 2. *Praehedbergella pseudosigali*.

TAXA APPEARING IN ZONE 2. As above, plus *Blefuscuiana aptiana aptiana, B. aptiana implana, B. occulta perforocculta*.

REMARKS. This zone represents the interval between the abundant and diverse assemblages of Zones 1 and 3, and typically contains relatively low numbers of taxa such as *Blefuscuiana aptiana s.s., B. aptiana implana* and *Praehedbergella grigelisi perforare*. The zone is difficult to identify unless it is in sequence with the other zones.

AGE AND STRATIGRAPHY. Zone 2 ranges from shortly beneath the Munk Marl Bed up to the top of the Barremian. The Munk Marl Bed is believed to correlate with the Batterton facies of eastern England (Speeton) and Germany, which is dated as late Early to early Middle Barremian (mid-*elegans* to mid-*fissicostatus* ammonite zones) (Rawson and Mutterlose, 1983). There is doubt whether the top of Zone 2 is Middle Barremian in age or whether it extends into the Late Barremian; this is partly due to the different subdivisions of the Barremian that are used (see, e.g. King *et al.*, 1989) and partly due to the possibility that the Late Barremian beds may be partly or wholly absent over much of the North Sea Basin. However, the top of Zone 2 corresponds to the first downhole occurrence of *Nannoconus abundans* (N), usually taken to mark the top of the Upper Barremian, and this is shortly succeeded downhole by the tops of *N. borealis* and

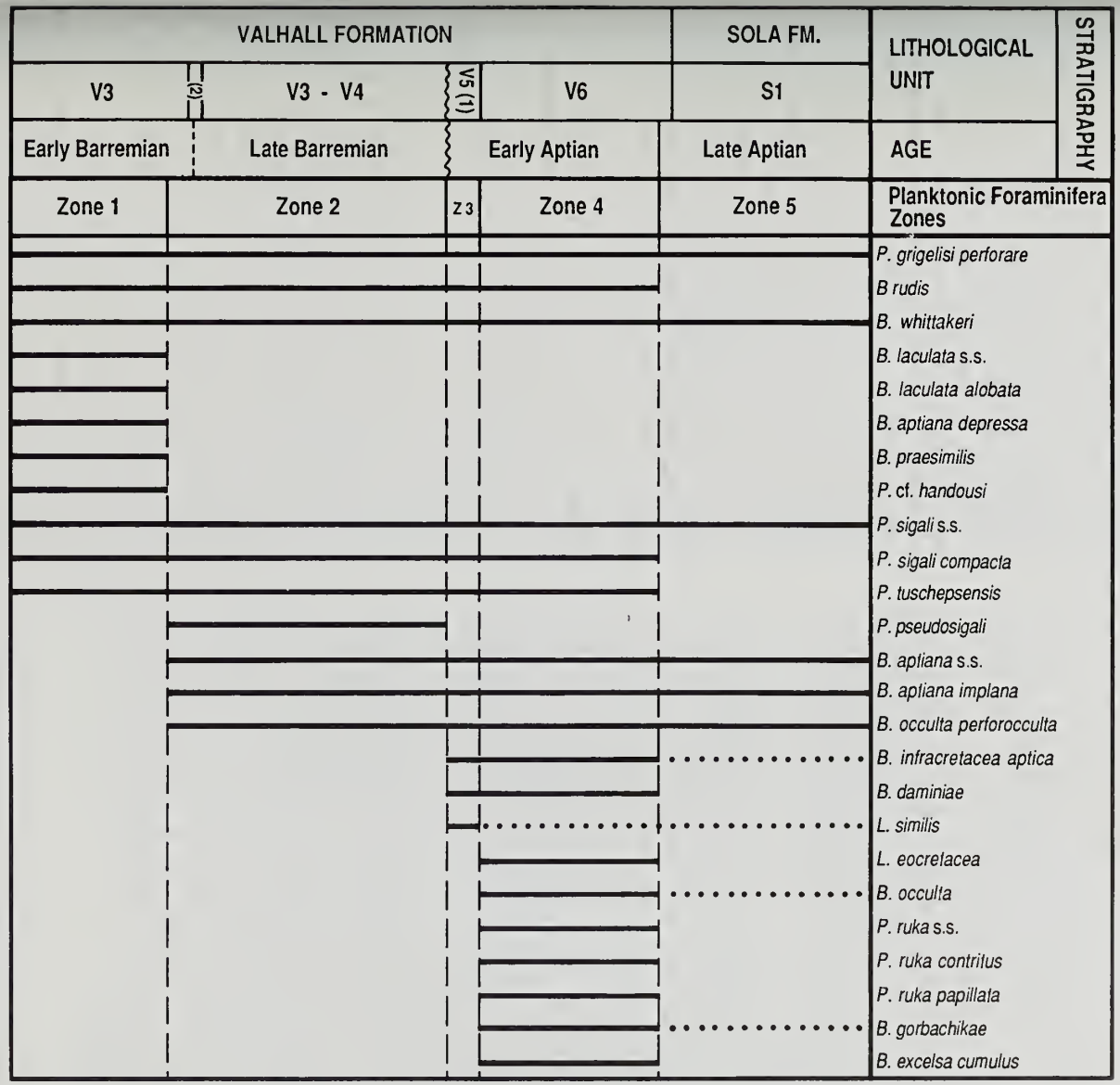

Fig. 4 Summary stratigraphical distribution of Central North Sea Barremian–Aptian Praehedbergellidae. Continuous stratigraphical lines: ranges as observed in samples from wells 15/30-3, 16/28-6RE and 20/2-2. Dotted stratigraphical lines: ranges extended from outcrop occurrences known elsewhere in the North Sea general region. (1) = Fischschiefer Member; (2) = Munk Marl Bed.

Conusphaera rothii (N), taken to indicate Middle Barremian age (Jakubowski, 1987).

Other taxa typically first occurring in Zone 2 include *Brizalina textularioides* (F) and *Gavelinella barremiana* (F). The first downhole occurrences of *Heslertonia heslertonensis, Hystrichodinium ramoides* and *Batioladinium longicornutum* (all D) occur at the top of the zone.

Zone 3

TAXA RESTRICTED TO ZONE 3. None.

TAXA APPEARING IN ZONE 3. *Lilliputianella similis* (not yet known above this zone in the North Sea wells, but known from younger beds at Speeton and elsewhere), *Blefuscuiana infracretacea aptica, B. daminiae.*

REMARKS. The planktonic foraminiferal assemblages of this zone are typically coloured grey with dark speckles of organic material, reflecting their origin in the organic-rich claystones of the V5 Unit. The praehedbergellids of this zone are often dominated numerically by *Blefuscuiana aptiana*, but seem also to be characterised by the appearance of the genus *Lilliputianella.*

AGE AND STRATIGRAPHY. This zone is restricted to the Fischschiefer Member (V5 Unit) of the Valhall Formation, a claystone unit distinguished by its high organic content with concomitant high gamma wireline log values and by large quantities of amorphous organic matter in the palynological assemblages. The Fischschiefer of the Lower Saxony Basin is generally considered to be of earliest Aptian age (cited by King *et al.*, 1989, p. 399, as belonging to the early *deshayesi* and *forbesi* ammonite zones), and its correlation with Unit V5, characterised by a horizon of abundance of '*Hedbergella* D9', has been noted by Crittenden *et al.* (1991). King *et al.* (1989) included it within 'Zone FCS7', the '*Hedbergella infracretacea* Zone'.

Associated benthonic foraminifera are not common, probably because of dysoxic conditions at or in the seabed during the time of deposition. The most consistently associated species is *Lenticulina kugleri* (F), with rare *Gavelinella barremiana* (F), even though the lowest and highest occurrences of the latter species were used by King *et al.* (1989, p. 399) to mark their subzone FCS6a, thought by them to be 'Middle Barremian'. The latter probably equates to the numerical increase of *G. barremiana* seen in the Barremian, but the species does range, in low numbers, into the Early Aptian, V6 Unit. Zone 3 is situated between the stratigraphic top common occurrence of *Lithiraphidites morayfirthensis* (N) (which occurs in Zone 4) and the stratigraphic base occurrence of this species.

Zone 4

TAXA RESTRICTED TO ZONE 4. *Praehedbergella ruka ruka, P. ruka contritus, P. ruka papillata, Blefuscuiana excelsa cumulus, Lilliputianella eocretacea.*

TAXA APPEARING IN ZONE 4. As above, plus *Blefuscuiana gorbachikae, B. occulta.*

TAXA DISAPPEARING IN ZONE 4. *Blefuscuiana daminiae, B. rudis, Praehedbergella sigali compacta, P. tuschepsensis.*

REMARKS. This zone is easily recognised in the North Sea by its abundance and diversity of praehedbergellid foraminifera and by the red colouration of its sediment and microfossils. Planktonic foraminifera can be so abundant as to form a fossil 'Globigerina ooze'; this also occurs in Heligoland, where the same deposit is called the 'Globigerinen-Kalk'. Consequently, the occurrence of the praehedbergellid assemblage of this zone has been previously reported by biostratigraphers, but the species present have been grouped as '*Hedbergella infracretacea*' (King *et al.*, 1989) or '*Hedbergella* D11 Hecht' (Crittenden *et al.*, 1991).

AGE AND STRATIGRAPHY. This zone is restricted to the red-brown, marl-limestone V6 Unit of the Valhall Formation, which has been correlated with the '*ewaldi* Marl' of Germany, Heligoland and eastern England (e.g. King *et al.*, 1989, who also included it in their 'subzone FCS7b', the FCS7b1 unit). The red-stained planktonic foraminiferal association of Zone 4 often contains abundances of *Valvulineria gracillima* (F). The Zone can also be noted by the disappearances of *Gavelinella barremiana* and *Lenticulina ouachensis* (F). Zone 4 also contains the first downhole common occurrence of *Lithiraphidites morayfirthensis* (N), an event used as an Early Aptian marker in the North Sea (Jakubowski, 1987). For this reason, Zone 4 is marked as being Early Aptian on Figure 4. However, a probably equivalent 'Red Mudstone' in Block 81 has ostracod assemblages which have been dated as Late Aptian (*nutfieldensis* and *martinioides* ammonite zones) as cited by Lott *et al.* (1985). In consequence, it is possible that Zone 4 may yet prove to span the Early Aptian–Late Aptian boundary.

Zone 5

TAXA RESTRICTED TO ZONE 5 OR APPEARING IN THIS ZONE. None known as yet, but see below.

TAXA DISAPPEARING IN THIS ZONE. *Blefuscuiana aptiana implana, B. occulta perforocculta, B. whittakeri, Praehedbergella sigali sigali.*

REMARKS. Zone 5 contains a less diverse assemblage than Zone 4, as some taxa appear to become extinct at its base, and the assemblages contain much less abundant specimens. Apparently due to palaeoceanographic circumstances which are, as yet, not elucidated, this zone contains the last occurrences of Praehedbergellidae in the North Sea wells. Further work must continue, especially on the correlation of this zone with the assemblages from Speeton (Banner and Desai, 1988) and its possible correlation with the *Leupoldina cabri* Zone or younger Aptian zones of more southerly outcrops. The praehedbergellids of Zone 5 are typically green, grey or brown stained, as they originate from the green-grey claystones of the lower Sola Formation (S1 Unit).

AGE AND STRATIGRAPHY. Zone 5 may be equated to the uppermost part of the '*Hedbergella infracretacea* Zone' (uppermost FCN7 or FCS7 Zones, the FCS7b2 or 'green *Hedbergella*' unit) of King *et al.* (1989, p. 398), which these authors suggested to be of middle Late Aptian (*nutfieldensis* ammonite zone) age (King *et al.*, 1989, figs. 8.3, 8.7). The age-equivalent assemblage had been reported by Lott *et al.* (1985, as '*Hedbergella infracretacea*') from well 81/40, in the Southern North Sea, and also dated as Late Aptian. Crittenden's (1987) green-stained '*Hedbergella infracretacea*' assemblage, also from Southern North Sea wells, is also referable to Zone 5; Crittenden (1987) also suggested a Late Aptian age (*nolani-jacobi* ammonite zones) for this interval from its

correlation with Germany. Crittenden *et al.* (1991) interpreted the age of the Northern North Sea green-stained '*H. infracretacea*' assemblage as being referable to the *nutfieldensis* ammonite zone, and considered the influx of planktonic foraminifera in the North Sea area to have been a transgressive event. A Late Aptian age is corroborated for the zone by the first downhole occurrences of *Aptea polymorpha* (D) and *Dingodinium albertii* (D) (Crittenden *et al.*, 1991). The downhole increase in *Ellipsoidictyum imperfectum* (cigar-shaped D), cited by these authors to occur with these events, actually occurs above, in the Albian.

The Central North Sea praehedbergellid assemblages reported in the present paper are clearly of the same age as the assemblages noted above in previous records. However, as the top of Zone 5 usually occurs below the highest (first downhole) palynological evidence of Upper Aptian, an intra-Late Aptian age for the upper boundary of this zone is preferred.

Associated with the praehedbergellids of Zone 5 are the first downhole occurrences of the benthic foraminifera (F) *Astacolus* cf *schloenbachi, Saracenaria spinosa, Gavelinella brielensis*, common *Valvulineria gracillima* and common *V. kasahstanica*. The benthic foraminifera, like the planktonic species, are commonly green stained.

Nannofossil occurrences provide important evidence for the age of this zone. Zone 5 contains the first downhole occurrences (stratigraphic tops) of *Micrantholithus hoschulzii, M. obtusus* and *Eprolithus varolii* (all N) with an increase in nannoconids (Jakubowski, 1987). Sissingh (1977) and Perch-Neilsen (1979) used the stratigraphic top of *M. hoschulzii* to define the top of the Lower Aptian, but later Perch-Nielsen (1985, p. 359) drew its range (and that of *M. obtusus*) to reach to the top of the Aptian; Jakubowski (1987) and Taylor (1982) have both recorded the first downhole occurrence of *M. hoschulzii* within the Upper Aptian of the North Sea area. Zone 5 contains the base occurrence of *Parhabdolithus angustus* (N); this is a well documented datum occurring near the base of the Upper Aptian worldwide (e.g. Perch-Nielsen, 1985, p. 341). This is shortly preceeded downsection by the top common *Rhagodiscus asper* (N), an event known within the Upper Aptian of onshore Germany (*nutfieldensis* ammonite zone) (Jakubowski, 1987). This supports the placement of Zone 5 within the *nutfieldensis* ammonite zone, Late Aptian.

Conclusions

The five informal zones which this reconnaissance has recognised span the interval from Early Barremian to Late Aptian. Beds of earliest Aptian age seem to be most easily recognised by the lowest stratigraphical occurrences of (morphologically primitive) *Lilliputianella*. The appearance of certain nannoplankton (e.g. *Rhagodiscus asper*) in the Late Aptian beds has been thought (Jakubowski, 1987) to reflect an influx of warm Tethyan water at this time; the same northward influx (deflected to its left by the Coriolis effect) may have brought *Leupoldina* and *Blowiella* to the west, near Speeton, but may have had little influence more eastwards, in the Central North Sea area. This may explain why these genera have not been found yet in Late Aptian beds of Central and Northern North Sea wells. It must also be remembered that Speeton is in a separate basin (the Southern North Sea Basin) from the basins of the Northern North Sea and Central North Sea, and is separated from them by the Mid North Sea High; the latter may have acted as a barrier to current flow and to microplanktonic migration. Also, differences in palaeoclimate may have had their effect. However, the species-group taxa of the Praehedbergellidae have considerable potential biostratigraphical value in the Barremian–Aptian interval of North Sea sediments, and their study should be pursued beyond this reconnaissance.

Acknowledgements. We are grateful to Dr G. Eaton (formerly of the BP Research Centre and now at The Natural History Museum, London) and to Dr S. Duxbury (now of Halliburton Geoconsultants) for initially suggesting the use of particular material from the Central North Sea. We thank BP Exploration Co Ltd for allowing the use of this well material and for permission to publish the results. We especially thank Professor A.R. Lord, Department of Geological Sciences, University College London, for his unfailing support and for the use of facilities (including the SEM) in the Postgraduate Micropalaeontology Unit of that Department. We also sincerely thank Drs B.T. Huber, M. Buzas and F.J. Collier, Department of Paleobiology, Smithsonian Institution, Washington, D.C., for their search for, and loan of, the metatypic specimens of *Globigerina infracretacea* Glaessner, and Dr J.E. Whittaker, The Natural History Museum, London, for preparing their SEM images which we use here, and for his support and encouragement during the preparation of this paper.

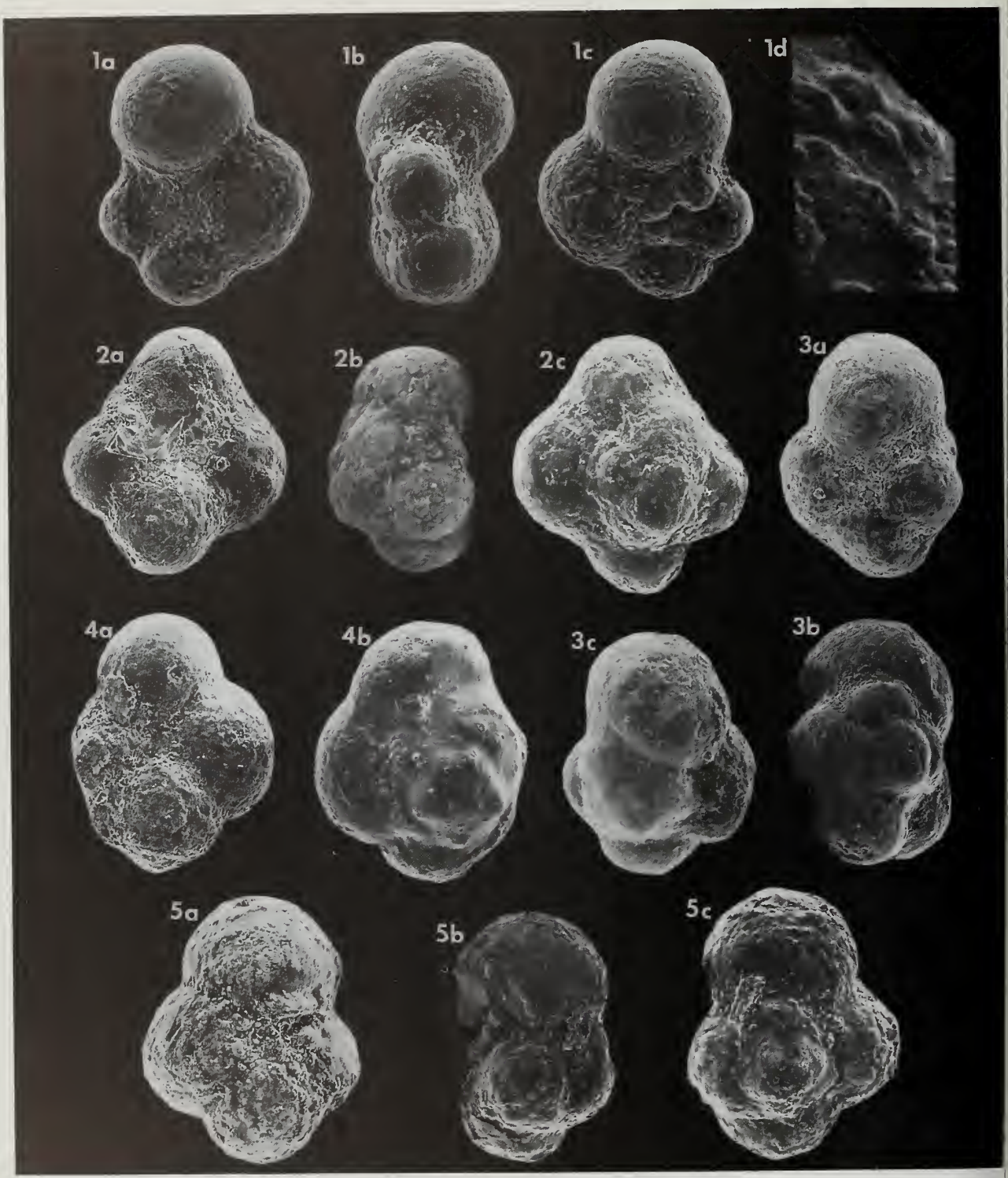

Plate 1

Fig.1 *Praehedbergella grigelisi* (Banner & Desai) *perforare* n.ssp. Early Aptian, Well 20/2–2, 8300 ft: a–c, ventral, peripheral and dorsal views of holotype, P52758, X 220; 1 d, perforation cones on holotype, X 2500.

Fig. 2 *Praehedbergella ruka* n.sp. *sensu stricto*. Early Aptian, Well 16/28–6RE, 4157.5 m: 2a–c, ventral, peripheral and dorsal views of holotype, P52739, X 315.

Figs 3–4 *Praehedbergella ruka contritus* n.ssp. 3a–c, Well 16/28–6RE, 3989.5 m, Late Aptian. Ventral, peripheral and dorsal views of holotype, P52737, X 330, 4a–b, Well 20/2–2, 8250 ft, Early Aptian. Ventral and dorsal views of paratype, P52738, X 300.

Fig. 5 *Praehedbergella ruka papillata* n.ssp. Early Aptian, Well I6/28–6RE, 4150 m: a–c, ventral, peripheral and dorsal views of holotype, P52736, X 315.

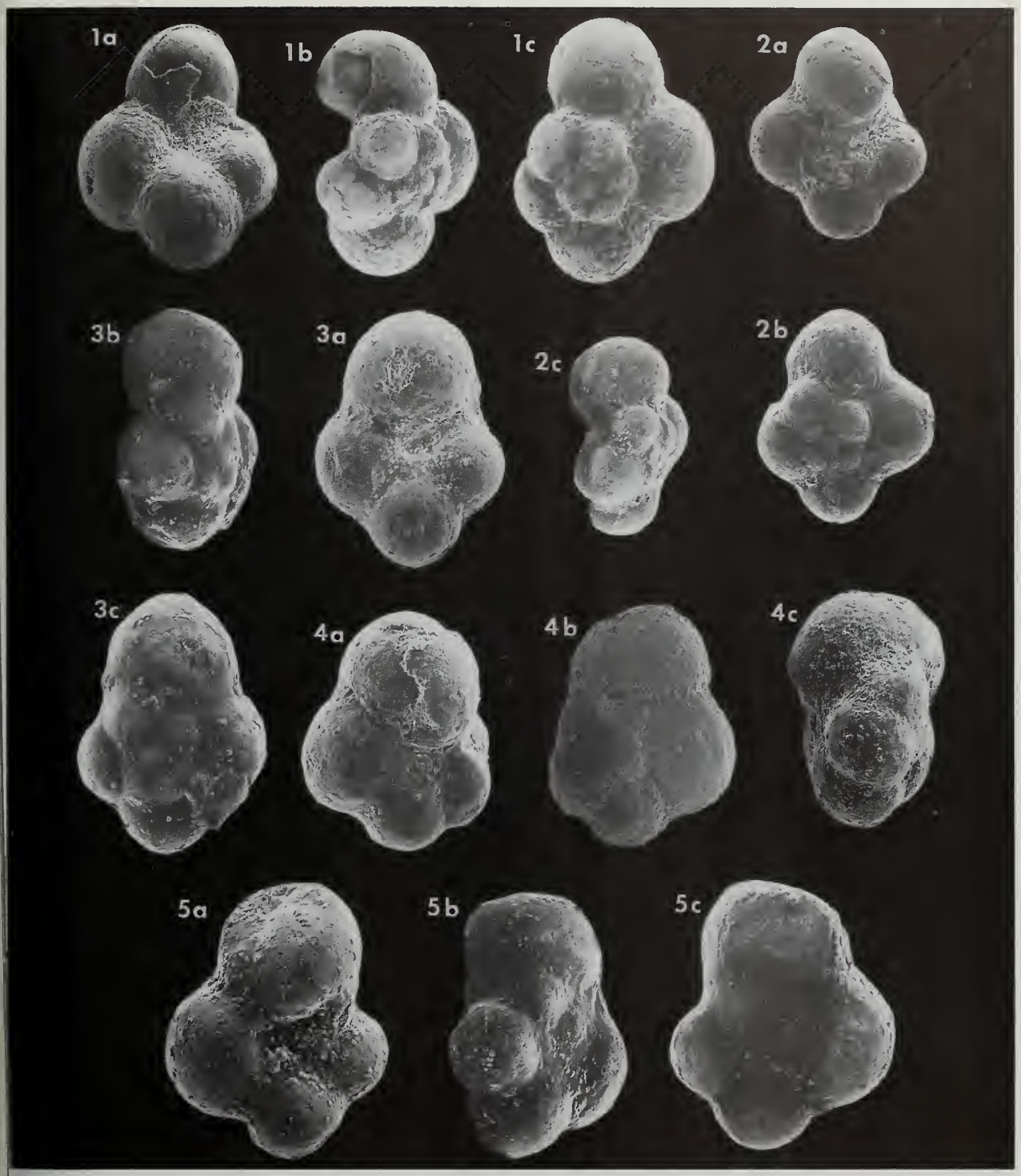

Plate 2

Fig.1 *Praehedbergella pseudosigali* n.sp. Late Barremian, Well 20/2–2, 8370 ft: a–c, ventral, peripheral and dorsal views of holotype, P52735, X 275.

Fig. 2 *Praehedbergella sigali sigali* (Moullade). Early Barremian, Well 20/2–2, 8680 ft: a–c, ventral, dorsal and peripheral views, P52742, X 280.

Fig. 3 *Praehedbergella sigali* (Moullade) *compacta* n.ssp. Early Barremian, Well 20/2–2, 8680 ft: a–c, ventral, peripheral and dorsal views, P52746, X 365.

Fig. 4 *Praehedbergella tuschepsensis* (Antonova). Early Aptian, Well 16/28–6RE, 4150.5 m: a–c, ventral, dorsal and peripheral views, P52733, X 240.

Fig. 5 *Praehedbergella* sp. cf. *P. handousi* (Salaj). Early Barremian, Well 20/2–2, 8680 ft: a–c, ventral, peripheral and dorsal views, P52734, X 350.

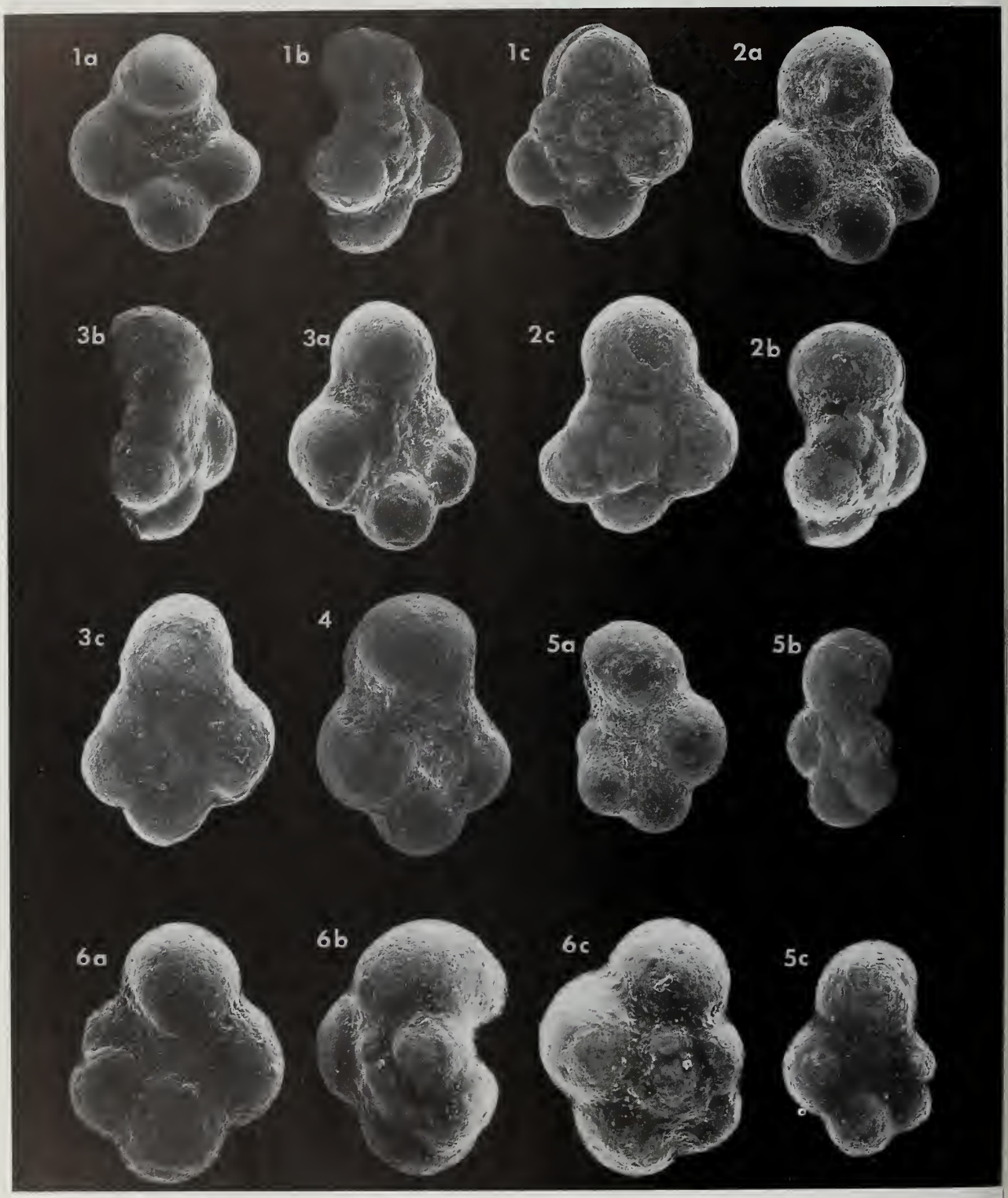

Plate 3

Figs 1–2 *Blefuscuiana laculata* n.sp. *sensu stricto*. Early Barremian, Well 20/2–2, 8680 m: 1a–c, ventral, peripheral and dorsal views of paratype P52725, X 210; 2a–c, ventral, peripheral and dorsal views of holotype, P52724, X 255.

Figs 3–5 *Blefuscuiana laculata alobata* n.subsp. Early Barremian, Well 20/2–2, 8680 m: 3a–c, ventral, peripheral and dorsal views of holotype, P52726, X 260; 4, ventral view of paratype P52728, X 250; 5a–c, ventral, peripheral and dorsal views of paratype P52727, X 250.

Fig. 6 *Blefuscuiana daminiae* n.sp. Early aptian, Well 15/30–3, 12830–40 ft: a–c, ventral, peripheral and dorsal views of holotype, P52696, X 220.

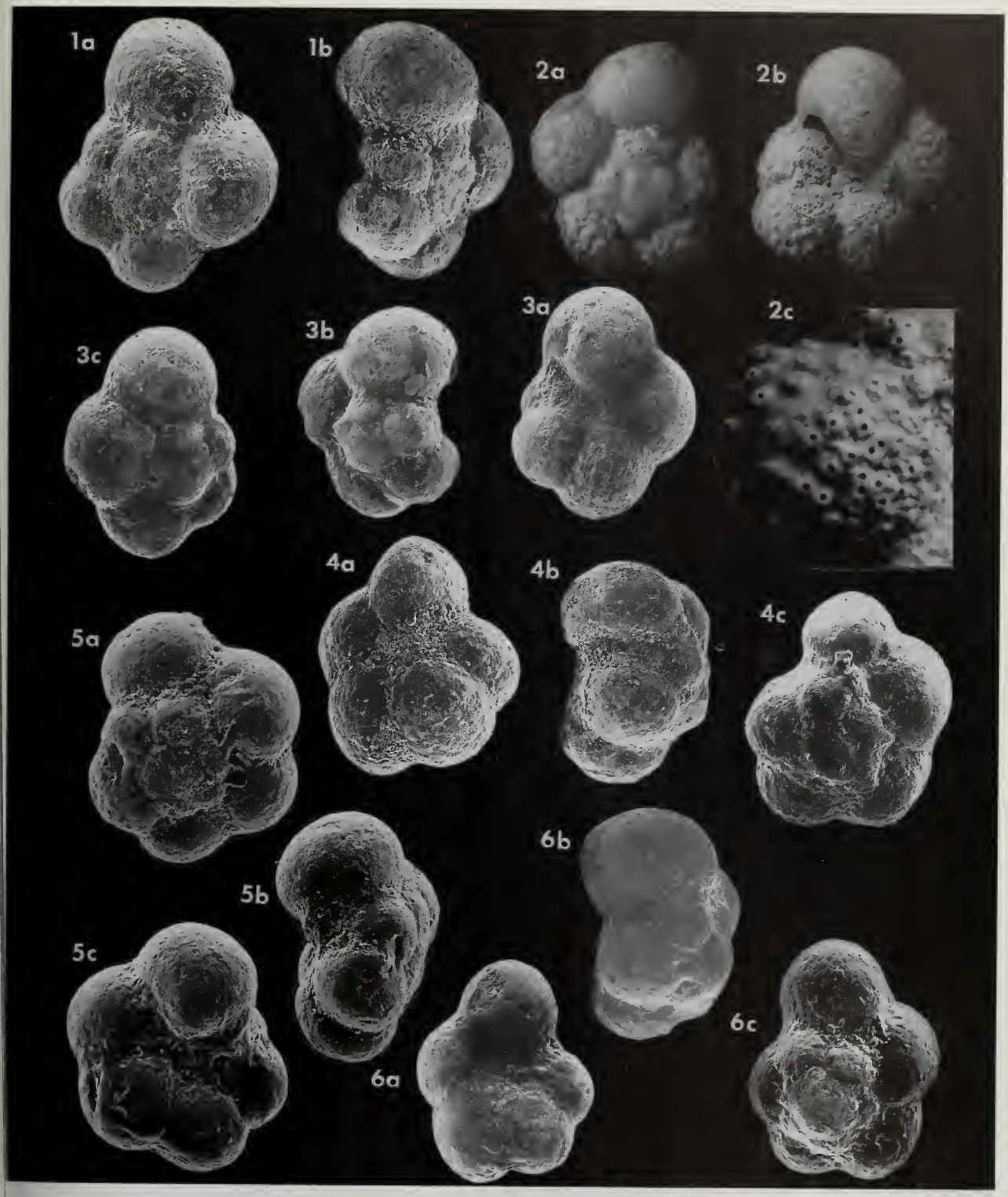

Plate 4

Fig. 1 *Blefuscuiana daminiae* n.sp. Early Aptian, Well 20/2–2, 8300 ft: a–b, dorsal and peripheral views of paratype, P52698, X 240.

Fig. 2 *Blefuscuiana infracretacea* (Glaessner), probable metatype, collected by M.F. Glaessner in 1935, from R. Ubin, Ilkaya, North Caucasus, 'Albian'; U.S. National Museum of Natural History, no. 689757; a–b, dorsal and ventral views, X 230; c, perforation-cones on ventral side of second chamber of last whorl, x 690.

Fig. 3 *Blefuscuiana daminiae* n.sp. Early Aptian: a–c, Well 15/30–3, 12830–40 ft. Ventral, peripheral and dorsal views of paratype, P52699 X 205.

Figs 4–6 *Blefuscuiana infracretacea* (Glaessner) *aptica* (Agalarova). Early Aptian. 4a–c, Well 15/30–3, 12830–40 ft; ventral, peripheral and dorsal views of P52701, X 250. 5a–c, Well 20/2–2, 8300 ft; ventral, peripheral and dorsal views of P52702, X 215. 6a–c, Well 15/30–3, 12830–40 ft; ventral, peripheral and dorsal views of P52682, X 200.

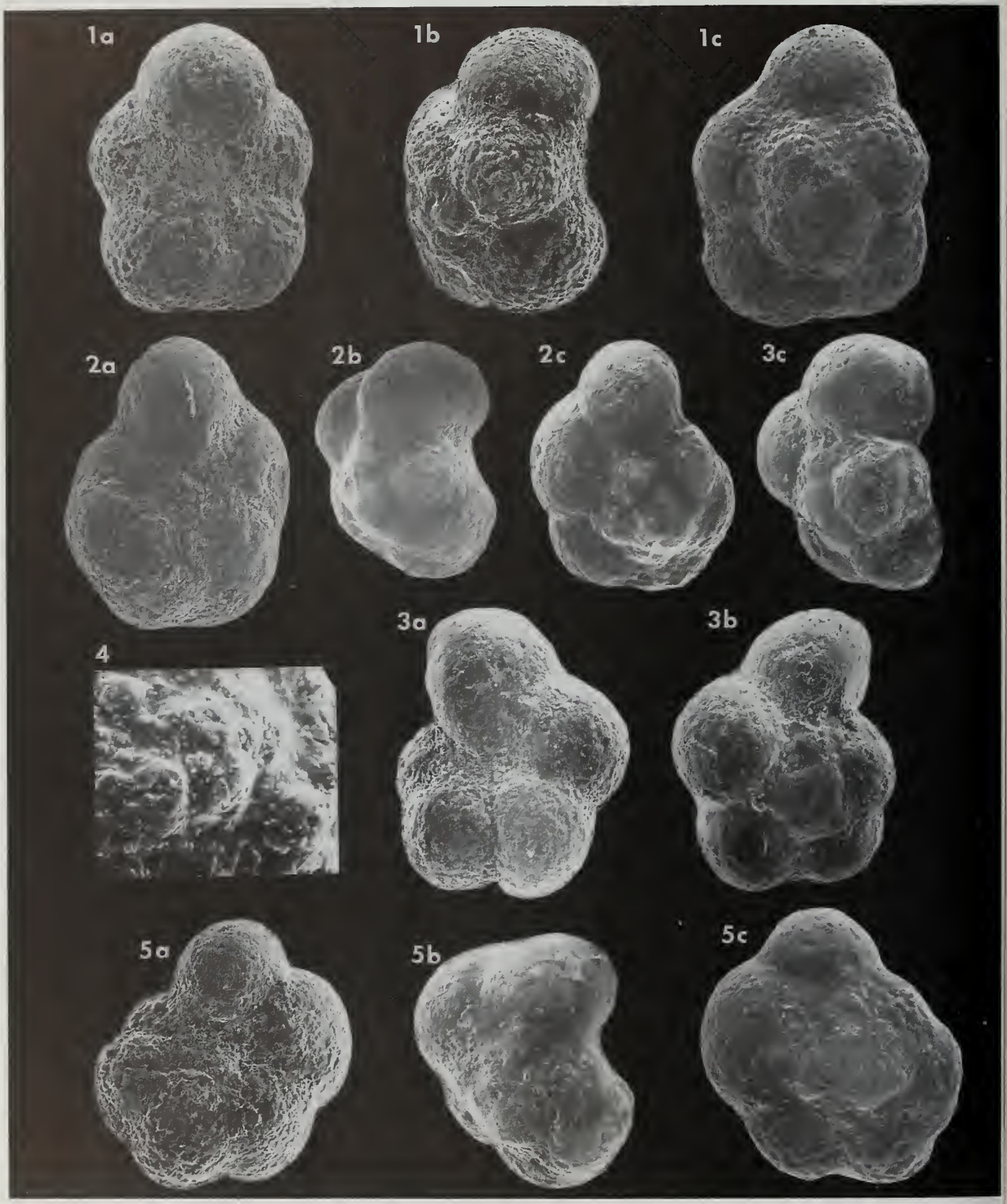

Plate 5

Fig.1 *Blefuscuiana rudis* n.sp. Early Barremian, Well 16/28–6RE, 4275 m; a–c, ventral, peripheral and dorsal views of holotype, P52713, x 200.

Fig. 2 *Blefuscuiana rudis* n.sp. Early Aptian, Well 20/2–2, 8250 ft; a–c, ventral, peripheral and dorsal views of paratype, P52715; a, x 430; b, c, x 360.

Figs 3–4 *Blefuscuiana whittakeri* n.sp. Early Aptian, Well 15/30–3, 12830–12840 ft; 3a–c, ventral, dorsal and peripheral views of holotype, P52717, x 290. 4, detail of perforation cones of holotype, x appr. 1160.

Fig. 5 *Blefuscuiana rudis* n.sp. Early Barremian, Well 16/28–6RE, 4195 m; ventral, peripheral and dorsal views of paratype, P52714, x 310.

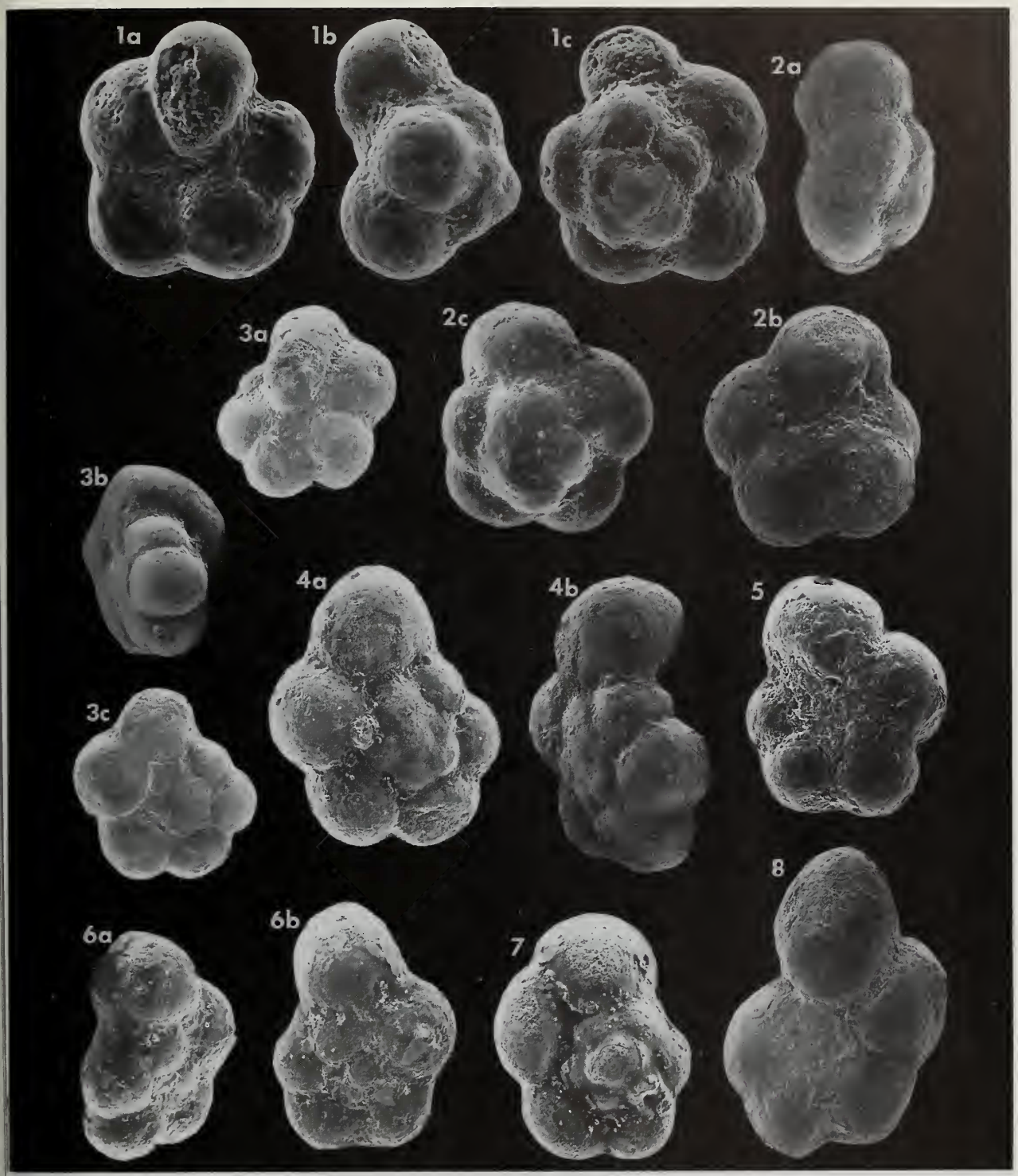

Plate 6

Figs 1–2 *Blefuscuiana excelsa* (Longoria) *cumulus* n.subsp. 1a–c, Early Aptian, Well 15/30–3, 12830–40 ft, ventral, peripheral and dorsal views of holotype, P52708, X 250. 2a–c, Early Aptian, Well 16/28–6RE, 4150.5 m, peripheral, ventral and dorsal views of paratype, P52709, X 240.

Fig. 3 *Blefuscuiana gorbachikae* (Longoria). Early Aptian, Well 16/28–6RE, 4150.5 m. Ventral, peripheral and dorsal views of P52687, X 170.

Figs 4–6 *Blefuscuiana aptiana aptiana* (Bartenstein). 4a–b, Early Aptian, Well 20/2–2, 8300 ft, dorsal and peripheral views of P52666, X 250. 5, Early Aptian, Well 16/28–6RE, 4178.5 m, ventral view of P52607, X 250. 6a–b, Early Aptian, Well 16/28–6RE, 4178.5 m, peripheral and dorsal views of P52665, X 325.

Fig. 7 *Blefuscuiana aptiana* (Bartenstein) *depressa* n.subsp. Early Aptian, Well 20/2–2, 8300 m. dorsal view of paratype P52712, X 250.

Fig. 8 *Lilliputianella eocretacea* (Neagu). Early Aptian, Well 16/28–6RE, 4160.7 m. Ventral view of P52732.

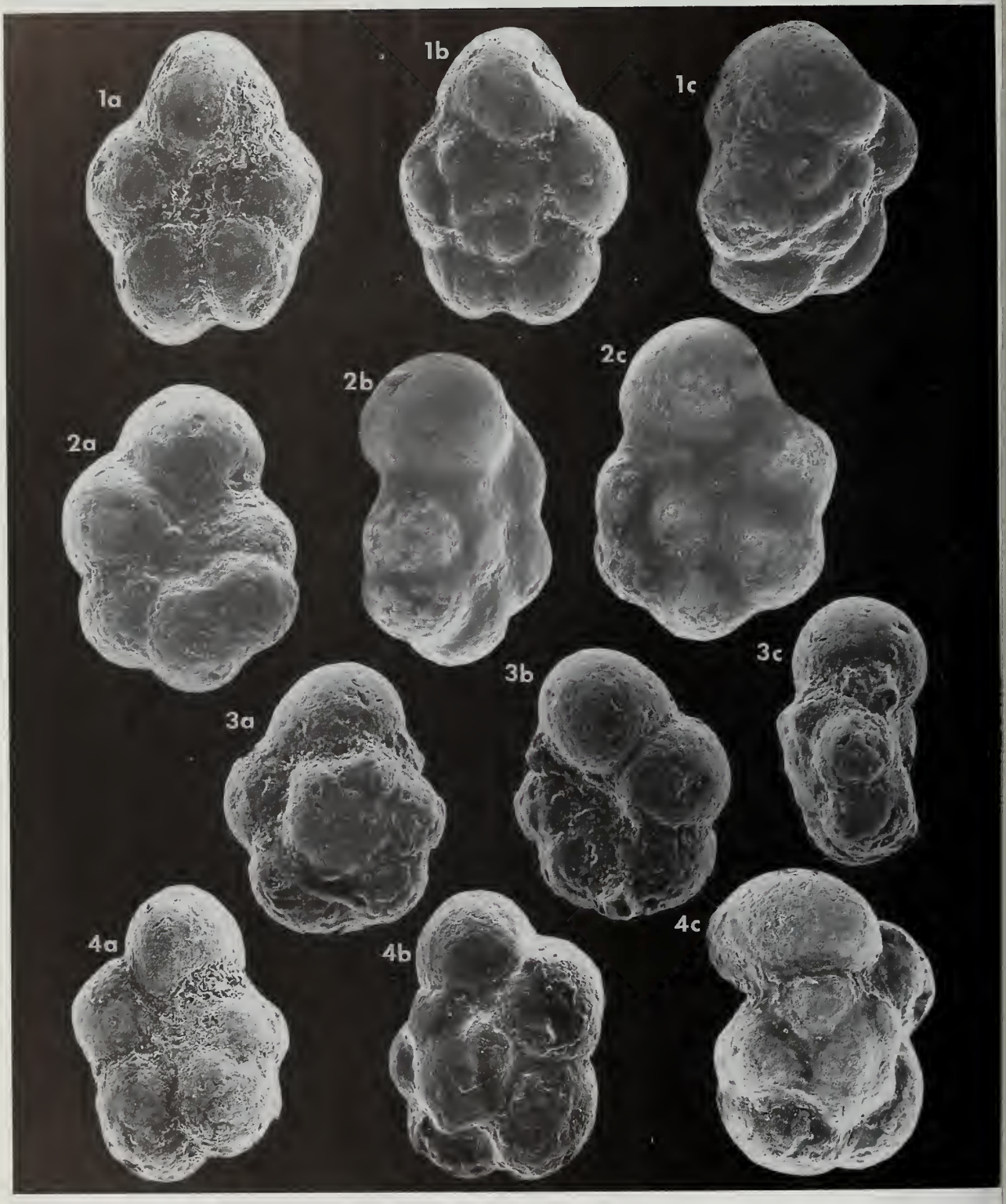

Plate 7

Fig.1 *Blefuscuiana aptiana* (Bartenstein) *depressa* n.subsp. Early Barremian, Well 16/28–6Re, 4260 m. a–c, ventral, peripheral and dorsal views of holotype, P52711, X 370.

Figs 2–4 *Blefuscuiana aptiana* (Bartenstein) *implana* n.subsp. 2a–c, Late Barremian, Well 20/2–2, 8370 ft, ventral, peripheral and dorsal views of paratype, P52707, X 250. 3a–b, Late Aptian, Well 20/2–2, 8210 ft, dorsal, ventral and peripheral views of holotype, P52705, X 260. 4a–b, Late Aptian, Well 20/2–2, 8210 ft, ventral, dorsal and peripheral views of paratype P52706, X 260.

Plate 8

Fig.1 *Blefuscuiana infracretacea* (Glaessner), probable metatype, collected by M.F. Glaessner in 1935, from R. Ubin, Ilkaya, North Caucasus, 'Albian'; U.S. National Museum of Natural History, slide no. 689757 (same slide as specimen figured Pl. 4, fig. 2); a, b, ventral and dorsal views, x 237; c, umbilical and apertural area, x 316.

Figs 2–3 *Blefuscuiana occulta* (Longoria) *perforocculta* n.ssp. Early Aptian, Well 20/2–2, 8300 ft. 2a–c, ventral, peripheral and dorsal views of holotype, P62677, X 175. 3, ventral view of paratype, P52678, X 180.

Figs 4–6 *Blefuscuiana praesimilis* n.sp. Early Barremian. 4a–c, Well 20/2–2, 8680 ft, ventral, peripheral and dorsal views of holotype, P52691, X 190. 5, Well 20/2–2, 8680 ft, ventral view of paratype, P52692, X 270; 6, Well 20/2–2, 8600 ft, ventral view of paratype, P52693, X 200.

Fig. 7 *Lilliputianella eocretacea* (Neagu). Early Aptian, Well 15/30–3, 12830–40 ft. Peripheral, ventral and dorsal views of P52731, X 230.

Fig. 8 *Lilliputianella similis* (Longoria). Early Aptian, Well 20/2–2, 8300 ft. Ventral, peripheral and dorsal views of P52730, X 210.

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